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THE

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOLUME IX.

BOSTON:
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1896.

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THE SOCIETY OF ARTS, established in conformity with the plan of the Massachusetts Institute of Technology as set forth in the act of incorporation, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the sciences and their practical applications, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce. Regular meetings are held semi-monthly from October to May.

The Society discontinued the publication of the *Abstracts of Proceedings* in 1891, and since then has published its proceedings and the principal papers read at its meetings in the *Technology Quarterly*. The present volume contains the proceedings from January to May, 1896, inclusive.

The *Quarterly* contains, also, the results of scientific investigations carried on at the Institute, and other papers of interest to its graduates and friends.

Nèither the Massachusetts Institute of Technology nor the Society of Arts assumes any responsibility for the opinions or statements in the papers.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Society of Arts.

OFFICERS, 1896–1897.

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Editor.

ROBERT P. BIGELOW.

BY-LAWS.

Objects of the Society.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind which they are willing to contribute to attend its meetings and become members. Persons having valuable inventions or discoveries which they wish to explain will find a suitable occasion in the Society meetings, subject to regulations hereafter provided; and while the Society will never indorse, by vote or diploma or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

Section I. — Administration.

The immediate management and control of the affairs of the Society of Arts shall be exercised by an Executive Committee, consisting of the President of the Institute and the Secretary of the Society (who shall be members *ex officiis*), and five other members, who shall be elected by the Society of Arts at each annual meeting, to continue in office until other persons have been chosen in their place.

Sect. II. — Duties of the Executive Committee.

The Executive Committee shall elect its chairman, prescribe his duties, and, with the concurrence of the Treasurer of the Institute, fix his compensation when the interests of the Society require that

he should be paid for his services; they may invite any person to preside at any ordinary meeting who is well versed in the subjects to be discussed; they shall appoint the days and times of meeting, when not fixed by the Society, and determine the subjects to be considered at the meetings and the mode of conducting the discussions; they may, with the concurrence of the President of the Institute, make such arrangements for reporting and publishing the proceedings of the Society as they may deem best suited to advance its interests; they may receive moneys in behalf of the Society in aid of its objects, by subscription, donation, or bequest; they shall make a report of their doings to the Society at its annual meeting and at such other times as a report may be called for by a majority of the members present at any meeting; they shall also make a report of their doings to the President of the Institute prior to the annual meeting, and at such other times as the Corporation may require it. Four members shall constitute a quorum for the transaction of business.

Sect. III. — Duties of the President and Secretary.

1. It shall be the duty of the President of the Institute to preside at the annual and the special meetings of the Society, and also at its ordinary meetings when the Executive Committee does not invite a special chairman to preside.

2. It shall be the duty of the Secretary of the Society to give notice of and attend all meetings of the Society and of the Executive Committee; to keep a record of the business and orders of each meeting, and read the same at the next meeting; to keep a list of the members of the Society, and notify them of their election and of their appointment on committees; and generally to devote his best efforts, under the direction of the Executive Committee, to forwarding the business and advancing the interests of the Society. He shall also record the names of the Executive Committee attending each meeting.

Sect. IV. — Funds of the Society.

All the fees and assessments of members, and all moneys received by subscription, donation, or otherwise, in aid of the Society, shall be paid into the treasury of the Corporation, to be held and used for the objects of the Society under the direction of the Executive Commit-

tee, and shall be subject to the order of its Chairman, countersigned by the President of the Corporation.

Sect. V. — Meetings of the Society.

1. The annual meeting of the Society shall be held at the Institute on the second Thursday in May. The ordinary meetings shall be held semi-monthly, or whenever deemed expedient by the Society or by the Executive Committee, excepting in the months of June, July, August, and September.

2. If from any cause the annual meeting shall not have been duly notified or held as above required, the same shall be notified and held at such time as the Executive Committee may direct.

3. A special meeting of the Society may at any time be called by the Secretary on a written request of ten members. Twelve members of the Society shall constitute a quorum for the transaction of business.

Sect. VI. — Members and Their Election.

1. Members of the Society of Arts shall be of three kinds — Associate, Corresponding, and Honorary Members.

2. Candidates for Associate Membership shall be recommended by not less than two members, whose signatures shall be affixed to a written or printed form to that effect. Each nomination shall be referred to the Executive Committee, and when reported favorably upon by them, and read by the Secretary, may be acted upon at the same meeting; the election shall be conducted by ballot, and affirmative votes to the number of three fourths of the votes cast shall be necessary for an election.

3. Corresponding and Honorary Members may be elected in the same way, on nomination by the Executive Committee.

4. Associate Members shall pay an admission fee of three dollars before being entitled to the privileges of membership, and an annual assessment of three dollars on the first of October of each year, this sum to include subscription to the *Technology Quarterly and Proceedings of the Society of Arts.*

An Associate Member who shall have paid at any one time the sum of fifty dollars, or annual assessments for twenty years, shall become a member for life, and be thereafter exempted from annual assessments.

A member neglecting to pay his annual assessment for six months after being notified that the same is due shall be regarded as having withdrawn his membership, unless otherwise decided by the Executive Committee, which shall be authorized, for cause shown, to remit the assessments for any one year; and which shall moreover be empowered to exempt particular members from assessments whenever their claims and the interests of the Society make it proper to do so.

Sect. VII. — Election of the Executive Committee and of the Secretary.

1. At an ordinary meeting of the Society, preceding the annual meeting, a nominating committee of *five* shall be chosen, whose duty it shall be to nominate candidates for the Executive Committee, to post a list of the names selected in the office of the Secretary, and to furnish printed copies thereof to the members at or before the time of election.

2. At a meeting at which an election is to take place the presiding officer shall appoint a committee to collect and count the votes and report the names and the number of votes for each candidate, whereupon he shall announce the same to the meeting.

3. A majority of the votes cast shall be necessary to an election.

4. In the first organization under these By-Laws, the Executive Committee may be elected at an ordinary or special meeting.

5. Vacancies in the committee occurring during the year may be filled by the Society at an ordinary meeting.

6. The Secretary shall be elected by the Society, on nomination by the Executive Committee, at each annual meeting of the Society, or, in case of a vacancy during the session, at such other time as the Executive Committee may appoint; and he shall be reëligible in the same way at the pleasure of the Society.

7. The compensation of the Secretary shall be fixed from year to year by the Executive Committee with the concurrence of the Treasurer of the Institute.

Sect. VIII. — Committees of Arts.

1. The Members of the Society of Arts may be enrolled in divisions, under the following heads, according to the taste or preference of

the individual; each division to constitute a committee upon the subjects to which it appertains:

(1) On Mineral Materials, Mining, and the Manufacture of Iron, Copper, and other Metals.

(2) On Organic Materials — their culture and preparation.

(3) On Tools and Implements.

(4) On Machinery and Motive Powers.

(5) On Textile Manufactures.

(6) On Manufactures of Wood, Leather, Paper, India Rubber, and Gutta Percha.

(7) On Pottery, Glass, Jewelry, and works in the Precious Metals.

(8) On Chemical Products and Processes.

(9) On Household Economy; including Warming, Illumination, Water-Supply, Drainage, Ventilation, and the Preparation and Preservation of Food.

(10) On Engineering, Architecture, and Ship-building.

(11) On Commerce, Marine Navigation, and Inland Transportation.

(12) On Agriculture and Rural Affairs.

(13) On the Graphic and Fine Arts.

(14) On Ordnance, Firearms, and Military Equipments.

(15) On Physical Apparatus.

2. Any member may belong to more than one of the above-named Committees of Arts, but shall not at the same time be eligible as chairman in more than one.

3. It shall be competent for each Committee of Arts, of ten or more members entitled to vote, to organize; to elect annually in October, or whenever a vacancy shall occur, a chairman; to appoint its own meetings; and to frame its own By-Laws, provided the same do not conflict with the regulations of the Society of Arts.

Sect. IX. — Amendment and Repeal.

1. These By-Laws may be amended or repealed, or other provisions added, by a vote of three fourths of the members present at any regular meeting of the Society; provided that such changes shall have been recommended and approved in accordance with the By-Laws of the Corporation (see extract from By-Laws of Corporation as

printed below) and presented in writing at a preceding meeting of the Society.

2. These By-Laws shall take effect immediately after their approval by the Corporation and adoption by the Society, and all previous By-Laws are hereby repealed.

EXTRACT FROM THE BY-LAWS OF THE CORPORATION.

The Committee on the Society of Arts shall consist of ten members, who shall have the general charge and supervision of the organization and proceedings of the Society, subject to the approval of the Corporation. It shall be their duty, in connection with a duly chosen committee of the same number of members of the Society, to form from time to time By-Laws for the government of the Society, which shall take effect when approved by the Corporation and adopted by the Society.

October, 1893.

LIST OF MEMBERS.

DECEMBER, 1896.

Members are requested to inform the Secretary of any change of address.

LIFE MEMBERS.

Addicks, J. Edward . . . . . Wilmington, Del.
Atkinson, Edward . . . . . 31 Milk Street, Boston, Mass.

Beal, James H. . . . . 104 Beacon Street, Boston, Mass.
Bouvé, Thomas T. . . . . 40 Newbury Street, Boston, Mass.
Bowditch, William I. . . . . 28 State Street, Boston, Mass.
Breed, Francis W. . . . . 111 Summer Street, Boston, Mass.
Bullard, W. S. . . . . 3 Commonwealth Avenue, Boston, Mass.

Carpenter, George O. . . . . 687 Boylston Street, Boston, Mass.
Cummings, John . . . . . 60 Congress Street, Boston, Mass.

Dalton, Charles H. . . 33 Commonwealth Avenue, Boston, Mass.
Davenport, Henry . . . 59 West 38th Street, New York, N. Y.
Dewson, F. A. . . . . 53 State Street, Boston, Mass.
Doane, Thomas . . . . . 8 Pearl Street, Charlestown, Mass.

Eastman, Ambrose . . . . . 53 State Street, Boston, Mass.
Endicott, William, Jr. . . . . 32 Beacon Street, Boston, Mass.

Fay, Joseph S. . . . . 88 Mount Vernon Street, Boston, Mass.
Forbes, John M. , ... 614 Sears Building, Boston, Mass.
Foster, John . . . . . 25 Marlborough Street, Boston, Mass.

Gaffield, Thomas . . . . . 54 Allen Street, Boston, Mass.
Griffin, Eugene . . . . . 323 State Street, Albany, N. Y.
Grover, William O. . . . . 17 Arlington Street, Boston, Mass.
Guild, Henry . . . . . 433 Washington Street, Boston, Mass.

Haven, Franklin . . . . 97 Mount Vernon Street, Boston, Mass.
Henck, J. B. . . . . Montecito, Santa Barbara Co., Cal.
Hewins, Edmund H. . . . . 625 Tremont Street, Boston, Mass.
Hyde, Henry D. . . . 380 Commonwealth Avenue, Boston, Mass.

Johnson, Samuel . . . . 7 Commonwealth Avenue, Boston, Mass.

Lee, Henry . . . . . Brookline, Mass.
Lincoln, F. W. . . . . Boston Storage Warehouse,
Massachusetts Avenue, Boston, Mass.
Little, James L. . . . . Goddard Avenue, Brookline, Mass.
Little, John M. . . . . Hotel Pelham, Boston, Mass.
Lowe, N. M. . . . . 88 Court Street, Boston, Mass.
Lowell, John . . . . . Chestnut Hill, Newton, Mass.
Lyman, Theodore . . . . . Brookline, Mass.

Mack, Thomas . . . . 269 Commonwealth Avenue, Boston, Mass.
Markoe, G. F. H. . . . . 36 India Street, Boston, Mass.
Matthews, Nathan . . . . . 145 Beacon Street, Boston, Mass.
May, F. W. G. . . . . 127 State Street, Boston, Mass.
May, John J. . . . . Post-Office Box 2348, Boston, Mass.
McPherson, W. J. . . . . 10 Clarendon Street, Boston, Mass.

Norton, Jacob . . . . . 67 Carver Street, Boston, Mass.

Ordway, John M. . . . . New Orleans, La.

Peabody, O. W. . . . . 113 Devonshire Street, Boston, Mass.
Pickering, E. C. . Harvard College Observatory, Cambridge, Mass.
Pickering, H. W. . . . . 249 Beacon Street, Boston, Mass.
Prang, Louis . . . . . 16 Centre Street, Roxbury, Mass.
Pratt, Miss . . . . . Watertown, Mass.

Ross, Waldo O. . . . . 1 Chestnut Street, Boston, Mass.

Ruggles, John . . . . . Chapel Station, Brookline, Mass.
Runkle, John D. . . Mass. Institute of Technology, Boston, Mass.

Sawyer, Edward . . . . . Newton, Mass.
Sawyer, Timothy T. . . . . 319 Dartmouth Street, Boston, Mass.
Sayles, Henry . . . . . 42 Beacon Street, Boston, Mass.
Sears, Philip H. . . . . 85 Mount Vernon Street, Boston, Mass.
Sherwin, Thomas . . . . . Revere Street, Jamaica Plain, Mass.
Shurtleff, A. M. . . . . 9 West Cedar Street, Boston, Mass.
Sinclair, A. D. . . . . 35 Newbury Street, Boston, Mass.
Stevens, B. F. . . . . 91 Pinckney Street, Boston, Mass.
Sullivan, Richard . . . . . 35 Brimmer Street, Boston, Mass.

Tufts, John W. . . . . 27 Concord Square, Boston, Mass.

Vose, George L. . . . . Paris, Me.

Ware, William R. . . . . Columbia College, New York, N. Y.
Watson, William . . . . 107 Marlborough Street, Boston, Mass.
Wentworth, Arioch . . . . . 332 Beacon Street, Boston, Mass.
Whitaker, Channing . . . . . Lowell, Mass.
Wing, Charles H. . . . . Ledger, Mitchell County, North Carolina.

ASSOCIATE MEMBERS.

Adams, Henry S. . . . . Arlington, Mass.
Alden, Charles H., Jr. . . 1740 R Street, N. W., Washington, D. C.
Alden, George A. . . . . 87 Summer Street, Boston, Mass.
Alden, John . . . . . Lawrence, Mass.
Allen, C. Frank . . Mass. Institute of Technology, Boston, Mass.
Allen, Samuel E. . . . . 67 Chauncy Street, Boston, Mass.
Allen, Walter S. . . . . 34 South 6th Street, New Bedford, Mass.
Allen, William Henry . 291 Commonwealth Avenue, Boston, Mass.
Andrews, Clement W. . . . . John Crerar Library, Chicago, Ill.
Appleton, Charles B. . . 207 Aspinwall Avenue, Brookline, Mass.
Atwood, Frank W. . . . . 98 Commercial Street, Boston, Mass.

Baker, J. B. . . . . 602 Centre Street, Newton, Mass.

Bardwell, F. L. . . Mass. Institute of Technology, Boston, Mass.
Barnes, Herbert H. . . . . Hotel Brunswick, Boston, Mass.
Barstow, George E. . . . . 27 Union Street, Lynn, Mass.
Bartlett, Dana P. . . Mass. Institute of Technology, Boston, Mass.
Bartlett, Spaulding . . . . . Webster, Mass.
Barton, George H. . Mass. Institute of Technology, Boston, Mass.
Barton, Howard R. . . . . Englewood, N. J.
Bassett, William H. . . . . New Bedford, Mass.
Batcheller, Robert . . 55 Commonwealth Avenue, Boston, Mass.
Beach, Charles B. . . . . 1183 Locust Street, Dubuque, Iowa.
Bigelow, Charles H. . . . . Salem, Mass.
Bigelow, Robert P. . Mass. Institute of Technology, Boston, Mass.
Binney, Amos . . . . Room 416, 53 State Street, Boston, Mass,
Birkholz, Hans . . . . . Care E. P. Allis Co., Milwaukee, Wis.
Bixby, George L. . . . . Foxboro, Mass.
Blodgett, George W. . . Boston and Albany Railroad, Boston, Mass.
Blood, Grosvenor T. . . . . 125 Milk Street, Boston, Mass.
Bowen, Stephen . . . . . 1 Elm Hill Avenue, Boston, Mass.
Bradlee, Arthur T. . . . . 113 Beacon Street, Boston, Mass.
Bradley, F. W. . . . . 202 Equitable Building, Boston, Mass.
Braley, Samuel T. . . . . Rutland, Vt.
Brophy, William . . . . 17 Egleston Street, Jamaica Plain, Mass.
Brown, Edward D. . . . . 18 Cortlandt Street, New York, N. Y.
Burns, Peter S. . . Mass. Institute of Technology, Boston, Mass.
Burton, A. E. . . . Mass. Institute of Technology, Boston, Mass.

Caldwell, Eliot L. . . . . 3 Head Place, Boston, Mass.
Cameron, J. A. . . . . Forge Village, Mass.
Carson, Howard A. . . . . 20 Beacon Street, Boston, Mass.
Carter, Henry H. . . . . Hotel Ludlow, Boston, Mass.
Carty, J. J. . . . . 18 Cortlandt Street, New York, N. Y.
Chandler, F. W. . . Mass. Institute of Technology, Boston, Mass.
Chandler, S. C. . . . . Cambridge, Mass.
Chase, Charles H. . . . . Stoneham, Mass.
Chase, F. D. . . . . Versailles, Pa.
Clark, John M. . . . . 47 Court Street, Boston, Mass.
Clifford, H. E. . . . Mass. Institute of Technology, Boston, Mass.
Cody, Lewis P. . . 9 South Division Street, Grand Rapids, Mich.

Coffin, C. A. . . . . General Electric Co., Boston, Mass.
Coffin, F. S. . . . . 152 Congress Street, Boston, Mass.
Collins, R. B. . . . . Box 237, Dedham, Mass.
Crafts, James M. . . . . 59 Marlborough Street, Boston, Mass.
Craig, J. Holly . . . . . 69 Broad Street, Boston, Mass.
Craigin, Henry A. . . . . 120 Broadway, New York, N. Y.
Crosby, William O. . Mass. Institute of Technology, Boston, Mass.
Crosby, William W. . . . . 8 Court Street, Woburn, Mass.
Cross, C. R. . . . Mass. Institute of Technology, Boston, Mass.
Curtis, Henry P. . . . . 94 Mount Vernon Place, Boston, Mass.
Cutter, Louis F. . . . . Winchester, Mass.

Dana, Gorham . . . . . 41 Allerton Street, Boston, Mass.
Day, Nathan B. . . . . 280 Newbury Street, Boston, Mass.
DeLancey, Darragh . . . . . Rochester, N. Y.
DeWolf, John O. . . . 33 Hampshire Street, Cambridgeport, Mass.
Drown, Thomas M. . . . Lehigh University, South Bethlehem, Pa.
Dudley, P. H. . . . . 80 Pine Street, New York, N. Y.
Dunn, Edward H. . . . . 30 South Street, Boston, Mass.
Dutton, Edgar F. . . . . Newton Centre, Mass.
Dwelley, Edwin F. . . . . 25 Baltimore Street, Lynn, Mass.

Ellis, John . . . . . Lonsdale, R. I.
Ely, Sumner B. . . . . 1213 Market Street, Harrisburg, Pa.
Eustis, W. E. C. . . . . 55 Kilby Street, Boston, Mass.
Eustis, W. Tracy . . . . . 950 Beacon Street, Brookline, Mass.
Evans, Robert D. . . . . 114 Bedford Street, Boston, Mass.

Farnham, Isaiah H. . . . . 125 Milk Street, Boston, Mass.
Faunce, Linus . . . Mass. Institute of Technology, Boston, Mass.
FitzGerald, Desmond . . . . . Brookline, Mass.
FitzGerald, Francis A. J. . Carborundum Co., Niagara Falls, N. Y.
Flinn, Richard J. . . . . West Roxbury, Mass.
Forbes, Eli . . . . . Clinton, Mass.
Forbes, Howard C. . . . . 31 State Street, Boston, Mass.
Foss, E. N. . . . . 8 Everett Street, Jamaica Plain, Mass.
Freeland, J. H. . . . . 651 Washington Street, Boston, Mass.
Freeman, John R. . . . . 4 Market Square, Providence, R. I.

French, E. V. . . . . 31 Milk Street, Boston, Mass.
French, William C. . . . . 651 Washington Street, Boston, Mass.
Fuller, William B. . . . 3 Mount Vernon Street, Boston, Mass.

Gaylord, W. K. . . . . Pasadena, Cal.
Gilbert, F. A. . . . . 74 Ames Building, Boston, Mass.
Gill, A. H. . . . . Mass. Institute of Technology, Boston, Mass.
Gilley, Frank M. . . . . 100 Clark Avenue, Chelsea, Mass.
Goodell, George H. . . . . Susquehanna, Pa.
Goodspeed, Joseph H. . 382 Commonwealth Avenue, Boston, Mass.
Goodwin, H. M. . . Mass. Institute of Technology, Boston, Mass.
Goodwin, Richard D. . . . . 28 Summer Street, Boston, Mass.
Gray, Joseph P. . . . . 31 Milk Street, Boston, Mass.
Greenleaf, Lewis S. . . 42 Farnsworth Street, South Boston, Mass.
Guppy, Benjamin Wilder . . . . . Melrose, Mass.

Hadaway, William S. . . . . 14 Edson Street, Boston, Mass.
Hadley, F. W. . . . . Arlington Heights, Mass.
Hale, Richard A. . . . . Lawrence, Mass.
Hamblett, George W. Mass. Institute of Technology, Boston, Mass.
Hamilton, George Wyman . . . . 28 Court Square, Boston, Mass.
Hardy, W. B. . . . . 63 Franklin Street, Boston, Mass.
Harrington, Francis . . . 5 Mount Vernon Street, Boston, Mass.
Harris, William A. . . . . Exchange, Liverpool, England.
Hart, Francis R., Old Colony Trust Co., Ames Building, Boston, Mass.
Hayes, Hammond V. . 42 Farnsworth Street, South Boston, Mass.
Hazen, Allen . . . . . 85 Water Street, Boston, Mass.
Hobbs, Franklin W. . . . . Brookline, Mass.
Hodgdon, Frank W. . . . . Arlington, Mass.
Hofman, H. O. . . Mass. Institute of Technology, Boston, Mass.
Hollingsworth, A. L. . . . . 64 Federal Street, Boston, Mass.
Hollingsworth, Sumner . . . . 44 Federal Street, Boston, Mass.
Holman, G. M. . . . . 52 Pleasant Street, Fitchburg, Mass.
Holman, S. W. . . Mass. Institute of Technology, Boston, Mass.
Holton, Edward C. . . . . 100 Canal Street, Cleveland, Ohio.
Holtzer, Charles W. . . . . Brookline, Mass.
Hood, George H. . . . . 9 Otis Street, Boston, Mass.
Hopkins, Prescott A. . . . . Drexel Institute, Philadelphia, Pa.

Hopkins, William J. . . . . Drexel Institute, Philadelphia, Pa.
Horton, Theodore . . . . . State House, Boston, Mass.
Howard, A. P. . . . . 13 Pearl Street, Boston, Mass.
Howe, Henry M. . . . . 287 Marlborough Street, Boston, Mass.
Howe, Horace J. . . . . Chestnut Street, Medford, Mass.
Hunt, Edward M. . . . . 22 Beckett Street, Portland, Me.
Hunt, Harry H. . . . . 202 Equitable Building, Boston, Mass.

Jackson, Daniel D. . Mass. Institute of Technology, Boston, Mass.
Jacques, W. W. . . . . 125 Milk Street, Boston, Mass.
Jenkins, Charles D. . . . . 32 Hawley Street, Boston, Mass.
Jenks, William J. . . . . 120 Broadway, New York, N. Y.
Johnston, William A. . Mass. Institute of Technology, Boston, Mass.
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VanDaell, A. N. . . Mass. Institute of Technology, Boston, Mass.
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Walker, Elton D. . . . . 16 Gillespie Street, Schenectady, N. Y.
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TECHNOLOGY QUARTERLY AND PROCEEDINGS OF THE SOCIETY OF ARTS

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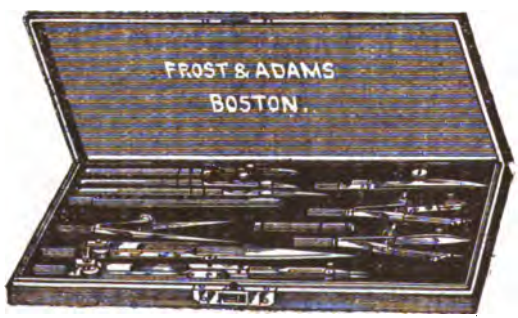

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TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. IX. MARCH, 1896. No. 1.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-FOURTH YEAR, 1895-96.

THURSDAY, January 9, 1896.

THE 479th meeting of the SOCIETY OF ARTS was held this day at the Institute, Room 22, Walker Building, Professor Cross in the chair.

The minutes of the last meeting were read and approved.

Professor William L. Puffer, of the Institute, then read a paper on "A New Method of Studying the Light of Alternating Arc Lights." The paper was illustrated by experiments, during which the image of the electric arc was projected upon the screen, so that all present could observe the effect of changes in the current and the appearance produced at various phases of the alternation.

A discussion and an exhibition of the apparatus followed, after which, on motion of Mr. Blodgett, it was voted to extend to the speaker the thanks of the Society for his very beautiful and elaborate experiments. The Society then adjourned.

THURSDAY, January 23, 1896.

The 480th meeting of the SOCIETY OF ARTS was held this day at the Institute, Room 22, Walker Building, the President in the chair.

The minutes of the last meeting were read and approved. Messrs. Henry S. Anderson, of Springfield, William H. Bassett, of New Bedford, Francis L. Gilman, of Wellesley, Fred M. Kimball, of Somerville, and Thomas P. Ritchie, of Newton Highlands, were duly elected Associate Members of the Society.

Professor James M. Crafts, of the Institute, read a paper on "Acetylene." The paper was fully illustrated by experiments showing the properties of the gas. The Society then adjourned.

THURSDAY, February 13, 1896.

The 481st meeting of the SOCIETY OF ARTS was held at the Institute, Walker Building, Room 22, on this day at 8 P.M., Mr. G. W. Blodgett in the chair.

The record of the last meeting was read and approved.

Mr. Louis Derr, of the Institute, read a paper on "Apparatus for Showing the Phase-Relations of Alternating Currents." The paper was illustrated by experiments with the apparatus, which consists, in part, of a revolving mirror and three mirrors attached to wires through which alternating currents may be passed. The oscillations of the wires due to the changes of phase in the current were rendered visible by means of beams of colored light reflected from the mirrors on the wires to the revolving mirror, and thence to the screen. In this way the phases of the currents in the three wires could be compared directly under various conditions, and were shown to correspond to the curves calculated mathematically.

Professor Cross then gave a demonstration of the "X-Rays of Röntgen." First, the direct effect of these rays on several fluorescent materials was shown, and then the same effect to a less degree was obtained when the Crookes tube was separated from the fluorescent material by plates of aluminium, vulcanite, etc. Quartz and glass, on the other hand, were shown to be opaque to the X-rays. In closing, Professor Cross mentioned experiments by Dr. Goodwin in which it was found that the X-rays affect the discharge of negative

electricity in the same way that the ultra-violet light rays do, and he suggested that this similarity to light may indicate a similar therapeutic value. The Society then adjourned.

THURSDAY, February 27, 1896.

The 482d meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., with Professor Swain in the chair.

The record of the last meeting was read and approved. Messrs. Robert B. Taber, of Cambridge, E. K. Turner, of Boston, John R. Freeman, of Providence, Rhode Island, Joseph P. Gray, of Boston, Eli Forbes, of Clinton, William B. Fuller, of Boston, Charles D. Jenkins, of Boston, Charles W. Holtzer, of Brookline, and Allen Hazen, of Boston, were duly elected Associate Members.

President T. C. Mendenhall, of the Worcester Polytechnic Institute, was then introduced, and read a paper on "The Alaska and Northeastern Boundary Line Disputes with England." The paper was illustrated with the lantern, by means of which there were exhibited maps showing the disputed boundary in Passamaquoddy Bay, and maps showing the lines claimed by England and America, respectively, between Alaska and the British possessions south of Mount St. Elias, together with views illustrating the topography of the country. A discussion followed, and then the President extended to the speaker the thanks of the Society for his very interesting paper, and the Society adjourned.

THURSDAY, March 12, 1896.

The 483d meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., Professor Lanza in the chair.

The record of the last meeting was read and approved. The following were duly elected Associate Members: Caryl D. Haskins and Sidney B. Paine, of Newton Centre, Samuel E. Allen and Frank W. Atwood, of Boston, Howard R. Barton, of Englewood, New Jersey, Grosvenor T. Blood, Stephen Bowen, and Frederick W. Bradley, of Boston, Samuel T. Braley, of Rutland, Vermont, George L. Bixby, of Elizabeth, New Jersey, J. A. Cameron, of Forge Village, F. D. Chase,

of Versailles, Pennsylvania, Lewis P. Cody, of Grand Rapids, Michigan, Henry A. Craigin, of New York, Gorham Dana, of Boston, Frank E. Davis, of Worcester, Nathan B. Day, of Boston, Darragh de Lancey, of Rochester, New York, John O. De Wolf, of Cambridge, Lawrence B. Dixon, of Chicago, Edwin F. Dwelley, of Lynn, John Ellis, of Lonsdale, Rhode Island, Sumner B. Ely, of Harrisburg, Pennsylvania, Francis A. J. Fitz Gerald, of Niagara Falls, New York, George H. Goodell, of Susquehanna, Pennsylvania, Benjamin Wilder Guppy, of Melrose, F. W. Hadley, of Boston, Richard A. Hale, of Lawrence, Frank W. Hodgdon, of Arlington, Edward C. Holton, of Cleveland, Ohio, Prescott A. Hopkins and William J. Hopkins, of Philadelphia, Harry H. Hunt, of Boston, Frank W. Lovejoy, of Cambridge, Clement March, of Bridgeport, Connecticut, Henry Martin, of South Gardiner, Maine, Frederick Metcalf, of Providence, Rhode Island, Leonard Metcalf, of Amherst, Burdett Moody, of Lead, South Dakota, P. A. Mosman, of Pueblo, Colorado, Luther R. Nash, of Boston, Arthur J. Ober, of West Medford, Joseph Y. Parce, Jr., of Denver, Colorado, Franklin A. Park, of Winchendon, Leo W. Pickert, of Boston, Clarence D. Pollock, of Brooklyn, New York, Howard S. Reynolds, of Braintree, Marion Talbot, of Chicago, Edward A. Tucker, of Melrose, Welland F. Sargent, of Chicago, Adelaide Sherman, of Roxbury, Frederick T. Snyder, of Milwaukee, Wisconsin, Henry Souther, of Hartford, Connecticut, Arthur B. Stoddard, of La Salle, Illinois, Charles A. Stone, of Boston, George W. Vaillant, of New York, Frank W. Very, of Hyde Park, Elton D. Walker, of Schnectady, New York, Roger J. Williams, of Canton, C. Nelson Wrightington, of Ludlow, and Fred G. Slawson, of Roxbury.

The following papers were presented by title: "Reduction of Nitrates by Bacteria and Consequent Loss of Nitrogen," by Ellen H. Richards and George William Rolfe; "Graduation of a 100-Inch Photometer Bar," by W. Lincoln Smith. These papers are printed in the present number of the *Quarterly.*

Professor Edward F. Miller, of the Institute, was then introduced, and read a paper on "A Duty Test of the Twenty-Million Gallon Leavitt Pumping Engine at Chestnut Hill." The paper was illustrated with the lantern. It will be published, with some additions, in the June number of the *Quarterly.* A discussion followed, and then, after a vote of thanks to the speaker for his interesting and valuable paper, the Society adjourned.

THURSDAY, March 26, 1896.

The 484th meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., the President in the chair.

The record of the last meeting was read and approved. Messrs. George E. Barstow, of Lynn, Spaulding Bartlett, of Webster, Charles B. Beach, of Dubuque, Iowa, Charles H. Bigelow, of Salem, A. Percy Brown and E. V. French, of Boston, W. K. Gaylord, of Pasadena, California, Lewis S. Greenleaf, of Boston, Edward M. Hunt, of Portland, Maine, W. R. Kales, of Cleveland, Ohio, Francis H. Kendall, of Cambridge, Joseph H. Kimball, of West Newton, Morris Knowles, 2d, of Boston, G. Frederick Knapp, of Philadelphia, L. Henry Kunhardt, of Boston, Franklin T. Miller, of Auburndale, Franz W. Schwarz, of Lawrence, H. C. Slater, of Ridley Park, Pennsylvania, J. M. Sully, of Chickamauga, Georgia, S. H. Thorndike, of Cambridge, Edwin S. Webster, of Boston, S. Edgar Whitaker, of Lynn, Thomas H. Wiggin, of Malden, W. H. Winkley, of West Medford, Richard J. Flinn, of West Roxbury, and Theodore Horton, of Boston, were duly elected Associate Members.

A paper on "The Sea Mills of Cephalonia," by F. W. Crosby and W. O. Crosby, was presented by title. It is printed in the present number of the *Quarterly*.

The President then introduced Mr. H. W. Clark, Chemist in Charge of the Experiment Station of the State Board of Health at Lawrence, who read a paper on "The Properties of Sands and Their Examination, with Special Reference to Their Use in Filtration." The paper will be published in the June number of the *Quarterly*. The reading of the paper was followed by a discussion, during which Professor Sedgwick spoke of the excellent work of Mr. Clark at Lawrence. The President thanked the speaker, and the Society adjourned.

ROBERT PAYNE BIGELOW, *Secretary*.

THE SEA MILLS OF CEPHALONIA.

By F. W. CROSBY and W. O. CROSBY.

Received March 24, 1896.

Description.

Greece is a country replete with geologic interest, but probably it presents no more curious or puzzling structural or dynamical phenomenon than the water power of the so-called Sea Mills near Argostoli on the island of Cephalonia. Our attention was first called to this phenomenon by the following statement in Baedeker's *Greece*. After giving a brief description of Argostoli, the chief town on the island of Cephalonia, Baedeker goes on to say: "From the Maitland Monument we may proceed along the coast, past the British Consulate and the large wine cellars of Mr. Toole, to the celebrated Sea Mills. The first of the latter is the mill of Dr. Migliaressi, established in 1859, and one fourth mile farther on, at the north end of the peninsula, is the old mill, erected by Mr. Stevens in 1835, where we obtain a better view of the phenomenon from whence the mills derive their name. The mills are driven by a current of sea-water, which flows into the land for about fifty yards through an artificial channel, finally disappearing amid clefts and fissures in the limestone rock. Authorities are not yet unanimous as to the explanation of this unique phenomenon."

The phenomenon appeared not only unprecedented, but contrary to nature. If she "abhors a vacuum," would she, could she, tolerate such a monstrous thing as an inverted river and vast, if not aching, voids, in realms beneath the sea for such an unnatural stream to flow into? Feeling thus somewhat incredulous as to the correctness of this account, despite the general reliability of Baedeker, the senior writer (F. W. Crosby) visited Argostoli and made a personal investigation.

Argostoli is on the southern coast of Cephalonia, on the landward side of a long, narrow ridge of limestone which forms its landlocked harbor. A mile north of the town, at the extremity of the prom-

ontory and the mouth of the harbor, are the Sea Mills. The entire promontory is composed of the ordinary bluish white Secondary limestone. It is nearly destitute of soil and vegetation, and the surface is very rough and ragged from unequal weathering. The land is low and flat at the north end in the vicinity of the mills, but it gradually rises as it trends southward, and between the town of Argostoli and Saint George's Castle, five or six miles distant, attains a height of 200 to 300 feet or more. Although Mr. Stevens, in 1835, was the first person to utilize this anomalous water power, the existence of the running water had long been known to the natives without exciting any special interest in their minds.

The mills have not been running for years, and are now in a state of dilapidation and decay. The many improvements lately made in the manufacture of flour and the building of large flouring mills at Patras and other places made it unprofitable to continue working these rude water mills, and they, as well as scores of windmills on the island, were abandoned.

Each race, or flume, is continued for a few yards beyond the mill, and terminates in an irregular pit excavated to a depth of 3 to 5 feet below the sea level. From this discharge pond, as it might be termed, the water rapidly disappears through numerous narrow openings, seemingly enlarged joint fissures. The races have a breadth of 4 to 6 feet, and the bottoms slope inland sufficiently to insure a strong current at the mills. The wheels in both mills were of the undershot type of rough country make, and connected by means of equally crude gearing to the millstones within the mill.

The only difficulty experienced in operating the mills was to prevent the ingress of seaweed and other trash which would choke up the discharge vents. At the Stevens Mill gratings were used for this purpose, but occasionally the crevices in the rock had to be cleaned out, as more or less weeds would get through the grating. Dr. Migliaressi, at the new mill, improved upon this by building a walled inclosure about 40 feet square in the sea around the mouth of the flume leading to his mill. The wall being laid without cement below the surface of the water, gave access to the water, but kept out the obstructing seaweed. In all other respects the mills were practically alike. The undershot water wheels were placed directly in the race, or flume, which at that point was incased with plank at sides and bottom. After passing the wheels the water is greedily

sucked in by the multitude of ever-thirsty mouths in the pit below; and although the wheels of the Sea Mills will never turn again, and are fast crumbling to decay, the water still flows unceasingly from the sea into the land.

The boundaries of this influx have never been definitely determined, but it certainly extends along the coast for nearly half a mile. At all points between the two mills, and for an unknown distance beyond each, the water is everywhere percolating through the cracks and fissures of the limestone and sinking into. the earth. The openings in the sea bottom around the point are, no doubt, mainly closed by weeds, gravel, etc., yet no inconsiderable amount of water must find its way to these mysterious depths through such an extent of beach, lying on a rock that is practically as porous as a sieve; and since this condition may prevail for a long distance from the shore, where the pressure would tend to increase the flow, we may reasonably assume the quantity of water absorbed outside of the mills as undoubtedly greater than that needed to run them. If we assume that each gristmill would require five horse power to operate it, and that the head of water actually used was about 3 feet, we must have a flow of at least 1,000 cubic feet per minute, or 2,000 per minute for the two mills; and we must double this amount to get even an approximate estimate of the magnitude of the inverted river at Argostoli. This assumption makes the daily consumption of water nearly 6,000,000 and the annual consumption over 2,000,000,000 cubic feet. If we imagine a cavern below we must give it generous proportions, as 2,000,000,000 cubic feet of water would fill a chamber about 5 miles long, 1,000 feet wide, and 75 feet deep. Or, if the water runs into a fissure, say 10 feet wide, it must be about 10 miles long and 4,000 feet deep to hold one year's influx at this point. When the second mill was built and put in operation it was soon noticed that the power of the old mill was perceptibly diminished; that is, either mill had a more copious discharge, and therefore more power, when the other was not running. We may conclude from this that the entire inflow is tributary to a single subterranean channel, and that it is not of sufficient capacity to allow a free discharge from both mills at once. Hence it follows that the building of the mills, with their head and tail races, and more especially the discharge pits, has probably added materially to the influx of water.

So far as we can learn, there is but a single reference to the

Sea Mills of Argostoli in any strictly scientific work. H. E. Strickland, an English geologist, visited Argostoli in 1835, just after the erection of the first mill, and published a brief but very good account of the phenomenon.[1] In his volume on *The Ocean* Reclus says, page 146: "When the waves of the sea cannot enter into the caverns remote from the shore except by narrow channels, it often happens that a rivulet of salt water regularly flows toward the interior of the land without ever returning to the ocean. This strange fact, which may seem at first sight a reversal of the laws of nature, may be observed at various points on the coast of calcareous countries, and especially on the coasts of Greece and the neighboring islands. Near Argostoli, a commercial town in the island of Cephalonia, four little torrents of sea-water, rolling on an average 55 gallons of water per second, penetrate into the fissures of the cliffs, flow rapidly among the blocks that are scattered over the rocky bed, and gradually disappear in the crevices of the soil. Two of these watercourses are sufficiently powerful to turn throughout the year the wheels of two mills constructed by an enterprising Englishman. Though the subterranean cavities of Argostoli are in constant communication with the sea, and the entrance to the canals is carefully freed from the seaweed that could obstruct the passage, or at least retard the current, the waters are not the same height in the grottoes as in the neighboring gulf. This is because the calcareous rocks of Cephalonia, dried on the surface by the sea breeze and the heat of the sun, are pierced and cracked throughout by innumerable crevices, which are so many flues aiding the circulation of the air and the evaporization of the hidden moisture. We can compare the entire mass of the hills of Argostoli, with all their caverns, to an immense *alcarraza*, the contents of which are gradually evaporated through the porous clay. In consequence of this constant loss of liquid, the level of the water is always lower in the caverns than in the sea, and to restore the equilibrium the brooklets, which are fed by the waves, descend incessantly by all the fissures toward the subterranean reservoirs. It is probable that the constant evaporation of the salt water has resulted in the accumulation in the cavities of the island of enormous saline masses. Professor Ansted has calculated that the discharge of the two great marine streams of Argostoli would

[1] Geological Society, London, Proceedings, 2, 220, 221.

be sufficient to form each year a block of more than 1,800 cubic yards of salt."

Searching among books of travel and tourists' handbooks has brought to light several references to the Sea Mills. John Davy, London, 1842, in giving a description of his sojourn among the islands, tells of the Sea Mills at Argostoli, which he did not see himself, obtaining his information from Dr. White. The description is fairly accurate, as the following quotation shows: "The next phenomenon I have to mention is very extraordinary, and apparently contrary to the order of nature. It is the flowing of the water of the sea into the land in currents or rivulets, which descend and are lost in the bowels of the earth. They flow with such rapidity that an enterprising Englishman has erected a gristmill, which is a great success." Farther on he observes, "It is only recently that it has been brought to the knowledge of the English, and it is now become a subject of curious inquiry and speculation."

In 1854 *Murray's Handbook for Greece* was written by G. F. Bowen. His account of the Sea Mills is taken *verbatim* from Davy. In 1863 a book on the Ionian Islands was published by Professor D. T. Ansted. On page 322 he refers to the Sea Mills as "a Cephalonian mystery." He says: "At four points on the coast the sea, at its ordinary level, enters a very narrow creek, or broken rocky channel, and disappears." There are no streams which could be called rivulets, except the artificial channels leading from the mills, but he is quite right in stating that "the water is greedily and rapidly absorbed by the whole surface between the two mills."

Professor Ansted has a theory for the disposition of the water. He says it must be evaporated. But in what manner he does not tell us, and he admits that he sees no way to dispose of the residual salts which would accrue from the evaporation of so great a volume of sea-water. He gives as a reason for holding to the evaporation idea the fact "that there are no springs on the island that present any large quantity of saline matter."

In 1846 Viscount Kirkwall's book, *Four Years in the Ionian Islands*, was published. After describing how the wonderful watercourses were first discovered and by whom the mills were built, we find on page 67 the following curious statement: "Admirals, generals, bishops, and distinguished civilian visitors seldom failed to examine this very interesting phenomenon."

It is difficult to decide which is the greater marvel, the Sea Mills themselves or the fact that they have remained practically unknown to the scientific world up to the present day, although described by several authors, mentioned in the guidebooks, and visited, as the viscount says, by "admirals, generals, bishops, and distinguished civilian visitors." Must we not conclude that "fair science" had no devotees among the titled crowd who from time to time looked wonderingly upon the "Cephalonian mystery"?

Proposed Explanation of the Sea Mills of Cephalonia.

No explanation of this phenomenon heretofore suggested is even measurably satisfactory. It cannot be connected in any way with tidal phenomena, because this part of the Mediterranean is almost tideless, and there is nothing periodic in the flow of the water into the land. That the water is simply filling a system of fissures and caverns in the earth is clearly inadmissible in view of the well-established facts. The flow of water into the land has certainly been uninterrupted since 1833, when first observed by Stevens, and Strickland stated in 1835[1] that it had been known to the Greeks for many years. Therefore a continuous downward flow for a full century appears to be a reasonable assumption, and a period of several or many centuries is, perhaps, not improbable. The supply of water is exhaustless, and the rate of downpour is limited only by the capacity of the fissures. The present rate of flow, or anything approaching it, continued for a century would give a total volume of water so prodigious as to far exceed the capacity of any known caverns. The force of this objection is augmented by the consideration that caverns other than fissures ("spaces of discission") must have been formed by solution of the rocks ("spaces of dissolution"), and have thus required for their formation a volume of water many times greater than that required to fill them. Furthermore, it is virtually an axiom in geology that all cavities in the earth below the drainage level of the district, and especially below sea level, except possibly those due to recent, sudden, and extensive rifting, must be permanently and continuously full of water, and certainly it is hardly conceivable that fracture fissures developed at the surface as mere

[1] Geological Society, London, Proceedings, 2, 220, 221.

cracks could require centuries for their filling with the sea pouring into them.

None of the suggested modifications of the cavern theory seems to be worthy of serious consideration. We cannot suppose that the water flows into caverns and disappears by evaporation or absorption. Both of these processes below a very moderate depth would necessarily be extremely slow, and the former would gradually fill the caverns with salt. Nor can we follow Strickland[1] in the supposition that an earthquake has at some period opened a communication between the sea and the region of volcanic fire, and that the water, being there converted into steam, is afterward condensed in its upward course and forms those hot springs which exist in various parts of Greece. Equally objectionable is the view that the water is absorbed at great depths by molten *magmas*. Volcanic phenomena are wholly wanting in this part of Greece; that is, there are no active, recently active, or extinct volcanoes nor, so far as we can learn, any geologically recent volcanic rocks. The great crater of Santorin is three hundred miles distant, while Cephalonia and the neighboring mainland consist of Secondary and Tertiary strata overlying ancient crystalline rocks.

The rejection of all these hypotheses forces us to the conclusion that in some way the water must return to the surface. A circulation due exclusively to hydrostatic pressure is manifestly impossible, unless, indeed, it should issue in the basin of the Dead Sea, a full thousand miles distant, since the water starts downward from the sea level. Still less can we suppose with Ansted that it would rise in the form of saline springs on the land.

It has occurred to us, however, that in the subterranean heat we have an adequate cause of aqueous circulation. The temperature of the ground increases downward, and it certainly is not a violent hypothesis that the water gains access to a system of fissures traversing a notable range of temperature. In this connection it may be noted that the conditions are favorable to profound fissuring; for Cephalonia, like the rest of Greece, is distinctly a seismic region — earthquakes, often of destructive severity, being of annual and almost monthly occurrence,[2] and the prevailing rock formation is the mas-

[1] Geological Society, London, Proceedings, 2, 220, 221.

[2] Memoirs Academy of Science, Dijon, 11 (1863), 1–112.

sive Cretaceous limestone, some thousands of feet in thickness. This rock forms the promontory of Argostoli and almost the entire island of Cephalonia, as well as neighboring islands, including Zante and many hundreds of square miles of the mainland. Strickland[1] describes it as "a hard, white limestone, abounding in faults and fractures, as well as caverns, subterranean rivers, and thermal and mineral springs, and presenting a close analogy to the Carboniferous limestone of Northern Europe." Limestone caverns are numerous in Cephalonia, and at two places there are deep holes, now small lakes, which were evidently formed by the breaking down of cavern roofs. That these caverns extend below sea level is proved by the fact that in boring an artesian well in Argostoli about a mile from the mills, a few years ago, the drill at a depth of about 225 feet broke into a cavern over 200 feet in depth, and the well was abandoned.

Water expands a little more than 4.3 per cent. between its temperature of maximum density and the boiling point, or say 1 per cent. for a difference in temperature of 40° Fahrenheit, corresponding, if we may postulate the normal temperature gradient, to a depth of 2,120 feet, or two fifths of a mile. The mean increase in temperature for this depth of the entire column of water may be assumed as one half the maximum, or 20°, corresponding to an expansion of one half of 1 per cent., or 10.6 feet in 2,120 feet. This head, which is quite as much as the Sea Mills call for, would be increased if the fissures increased in size downward, so as to bring the greater volume of water in the hotter zone, and *vice versa.* Doubtless in a single simple fissure extending to a depth of 2,000 feet, and ending there, a circulation, or process of convection, would be established, as in the case of a vessel of water over a fire — warm water rising in certain parts of the fissure, determined by trifling accidents of form, and cold water sinking in other parts; but of course no head or marked difference of level could arise under these conditions. Therefore in this simple form the hypothesis of a thermal circulation does not explain the Sea Mills. But this difficulty is obviated if we conceive two fissures converging downward and communicating at a depth of several thousand feet, like the two limbs of a gigantic letter V or U, the water descending in one fissure and ascending in the other. A contracted inlet would still be required, apparently, to

[1] Geological Society, London, Proceedings, 2, 572.

give an efficient water power or a clear fall of several feet, and the velocity of flow throughout the system would, of course, be inversely proportional to the section of the fissure.

Our first conception was that a special or local source of heat adjacent to the upflow branch of the system of fissures (x, Fig. 1) would be essential to an efficient circulation, but it now appears that even in a quite symmetrical arrangement of fissures and with strictly horizontal isogeotherms (Fig. 2) some slight inequality might determine movement of the water in a definite direction, down one fissure and up the other; and that such a movement once established would be accelerated by the circumstance that, in consequence of the movement, the downflow fissure is filled almost to the bottom with cold water or water that has experienced only a slight rise of temperature, while the upflow fissure is filled throughout with relatively warm water.

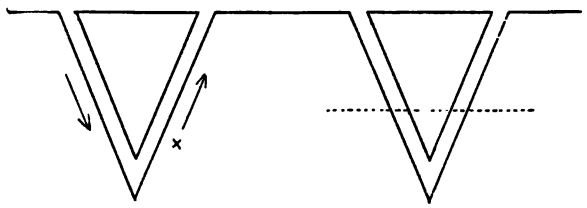

FIG. 1.

FIG. 2.

It is very obvious, however, that a much more decided and active circulation would result with an unsymmetrical or one-sided arrangement of the fissures (Fig. 3). Conceive one fissure as highly inclined or vertical, at least in its lowest part, and the other as rising at first in a very oblique or nearly horizontal direction from its lowest part, so as to be relatively long in the zone of highest temperature, and then reaching the surface by a more direct course, so as to be relatively short in the zone of lowest temperature. This is certainly not an improbable arrangement, and it provides the mechanism for a strong circulation of the water; for below any given isotherm, as that indicated by the dotted line in the figure, a much longer column of water is exposed to the higher temperature on one

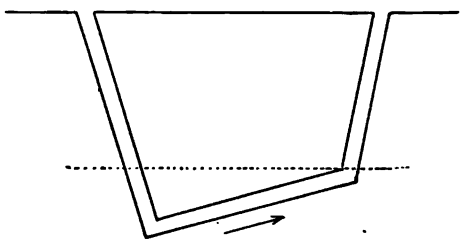

FIG. 3.

side of the lowest or turning point than on the other, and each part of this longer column has a longer time in which to absorb the heat of the rocks. It is even conceivable that with such an arrangement of the fissures the outlet may stand at a somewhat higher level than the inlet, and the sea-water springs imagined by one writer would thus appear not to be an impossibility. But the location of the Sea Mills of Argostoli on the extremity of a narrow promontory, and the absence in all that region, so far as known, of saline springs, make it extremely probable that the circulation terminates in this case on the sea bottom and thus escapes observation. Although we might think of the silt on the sea bottom as tending to choke up the subterranean fissures and prevent an influx of sea-water, it could not prevent the efflux movement.

Professor Moseley mentions[1] that during a submarine eruption off Hawaii in 1877 a fissure opened on the coast of that island from a few inches to three feet broad, and in some places the water was seen pouring down the opening into the abyss below. And Geikie says[2]: "The floor of the sea and the beds of rivers and lakes are all leaky. Moreover, during volcanic eruptions and earthquakes fissures no doubt open under the sea, as they do on land, and allow the oceanic water to find access to the interior. Rain water also penetrates along joint cracks and through the pores of rocks."

The existence of fissures or cracks in the earth's crust extending from the surface to depths where the rocks are highly heated requires no special argument, for the phenomena of volcanoes and thermal springs and of dikes and veins afford abundant evidence. It is now generally conceded that these earth fractures may maintain themselves as open fissures at depths far below that at which the rocks have the temperature of boiling water (212° F.), and the elevation of the boiling point by pressure must permit greater expansion and diminution of density, and therefore increased vigor of circulation.

The seismic records show not only that severe earthquakes are of almost annual occurrence in Greece, but also that they frequently result in the formation of extensive rifts and fissures; and the extremely hard and rigid Secondary limestone, and the crystalline rocks on which it rests, are alike favorable to the persistence in depth of

[1] Notes by a Naturalist on the Challenger, page 503.

[2] Text-book of Geology, page 265.

these earthquake fissures, which thus afford more or less permanent channels for a profound circulation of the subterranean waters. For a more detailed view of the earthquake phenomena of this region in their relations to the underground circulation we need refer only to the latest of the more severe Grecian earthquakes. From August, 1892, till May, 1893, the island of Zante, lying next south of Cephalonia in the Ionian Sea, with less than ten miles of water intervening, experienced almost daily tremors and shocks of varying intensity. The seismic disturbance culminated on January 31 and April 17, when almost the entire island was so completely devastated that out of 4,500 houses in the capital of the island 2,000 were wholly destroyed, 1,700 were so badly injured as to necessitate rebuilding, 700 required more or less extensive repairs, and only 100 were not seriously injured. The loss of life was also considerable.[1] The focus of these shocks is placed by Mitzopulos at a great depth under the narrow breadth of sea separating Zante from the mainland.

A little more than a year later, on April 20 and 27, 1894, and in this case without warning tremors, occurred two other disastrous shocks, this time in the province of Lokris, in the northeastern part of Greece, 100 to 150 miles east of Cephalonia. These earthquakes, which caused the death of 255 persons, have been very fully and ably described by Dr. Theodor G. Skuphos,[2] and the district affected was visited within a few days after the second shock by the senior writer. Skuphos shows that these shocks originated along a line parallel with the Channel of Atalanti, which separates the large island of Eubœa from the mainland, and he finds the mean depth of the *centrum* to be 6,992 meters for the first shock and 11,000 meters for the second. Rifts and fissures are among the most notable geological results of these shocks. Besides the main fissure, which has a length of 55 to 60 kilometers parallel with the shore, there is an extended network of minor fissures, often of sensible width and, like the main fissure, not uncommonly accompanied by a surface displacement of 1 to 2 meters. The influence of these fissures upon the circulation of the ground water was very marked, and some of the facts have an obvious bearing upon the problem of

[1] "Das grosse Erdbeben auf der Insel Zante im Jahre, 1893," by Professor Dr. K. Mitzopulos. Petermann's Mitteilungen, 39 (1893), 166–174.

[2] Zeitschrift Gesellschaft Erdkunde, Berlin, 29 (1894), 409–474.

the Sea Mills. Thus we read that the brackish water springs at Pikraki, which furnished sufficient water to drive a mill, completely disappeared after the first shock and returned with greatly increased volume after the second. Also the river-like springs of brackish water which furnished power for a mill at Halmyra were completely swallowed up by the great fissure for sixty hours, and now the flow of water is twice as great as before the earthquake. The water supply of the city of Atalanti has been increased threefold, while the supplies of other places, as Pasari, have permanently disappeared or the water can only be heard rushing in the fissures at a great depth. The wells of Kasna and Dumpioti have a greatly increased flow, which Skuphos connects with the disappearance of the water at Pasari. Springs near Atalanti which furnished power for several small mills have now greatly increased flow. In like manner along the entire length of the great fissure have the wells, springs, and surface streams experienced in general a notable increase or decrease of water in consequence of the earthquakes. Especially remarkable is a spring at the village of Masi, which before the earthquake furnished potable water, but is now brackish. A similar change in the character of the water is noted also at Halmyra and other places. On the island of Eubœa these phenomena are still more marked. Thus at Ædipsos the number of medicinal springs was doubled and the flow of water increased tenfold. These springs are thermal, and occur in three valleys or ravines. Those in the first valley range in temperature from 41° to 70° C. The most copious springs are in the second valley, with a temperature of 70° C.; while in the neighboring village of Platanos the water again gushes freely, sometimes to a height of a meter, from fifty old vents which had been dry for many centuries, the temperature of the water ranging from 70° to 82° C., and the other springs of the neighborhood have risen from 28° to 55° C. In the third valley the new springs have temperatures of 81° to 82° C. Along the entire course of the stream supplied by these springs (Thermopotamos) many new springs, with a temperature of 81° C., have appeared. The water of the old spring of Hagii Anargyri is diminished, and its temperature has risen from 77° to 80° C. In the old spring basins of the Sylla Baths new springs have appeared, with temperatures of 77° and 78° C., and on the peninsula of Prophet Elias the springs have increased in volume, and the temperature has risen from 31° to 44° C.

These are significant facts, and they appear to prove not only an intimate connection between the earthquake fissures and the underground aqueous circulation, but also that this circulation is sufficiently profound to give rise to numerous thermal springs. Again, no facts are known to us which militate against the view that the brackish springs represent a subterranean circulation which originates in the sea, the sea-water becoming diluted during its underground passage. Certainly the enormous volumes of water which these saline springs discharge, and have discharged continuously for decades and centuries, are unfavorable to the view that they have derived their salt from unknown saliferous strata. They are near the sea and, so far as we can learn, near sea level, and in the absence of definite indications to the contrary may, perhaps, fairly be assumed to mark the exits or return currents of some such streams of sea-water as we see pouring down into the land in the Sea Mills of Argostoli. Temperature data are, of course, desirable to show whether these saline springs are always warmer than the adjacent sea, and in the absence of such data a positive statement as to the source of the water would not be justified.

An examination of our best general works on geology leaves the impression that the subterranean heat has been somewhat neglected as a cause of the circulation of water through the rocks. With its aid we can explain an active and efficient circulation in the deep region or far below the base level of the district, and a source above the base level appears, as Posepny has hinted,[1] not to be strictly essential to the theories of thermal springs and artesian wells. In other words, while the underground circulation is conditioned primarily by structure, the motive power is derived from either the subterranean heat or a topographic head — a difference of density or a difference of level. These two dynamic causes may cöoperate, they may act more or less independently, or they may antagonize each other; and, as noted, it is at least conceivable that a spring, impelled by the subterranean heat, may rise above its source.

It is generally conceded that, under the influence of the tremendous subterranean pressures, aided by capillary attraction, water pervades all rocks; but it is also recognized that anything like a definite or rapid circulation of the water can only take place in fissures or con-

[1] Transactions American Institute of Mining Engineers, 23, 217.

tinuous cavities of some sort (spaces of discission or dissolution) or through the more porous strata, such as the coarser fragmental rocks. The phenomena of artesian wells and springs show that porous strata afford very efficient water channels, and no reason is apparent why the subterranean heat should not promote the circulation through these as well as through the open fissures. Hence we may conceive that in a deep circulation originating in the subterranean heat a part or the whole of the system of fissures may be replaced by porous strata. Thus the water may, as commonly represented, descend along an inclined porous stratum and rise to the surface through an intercepting fissure (fault line or master joint) or an artesian well. Or it may descend along one limb of a synclinal fold and rise along the other, and then the form of the fold, whether symmetrical or unsymmetrical, becomes a matter of import; and, just as in the unsymmetrical system of fissures, the water will, other conditions favoring, descend along the limb of highest dip and ascend along the limb of lowest dip. As Posepny suggests, the apparent head of an artesian or other deep circulation may be fully neutralized by the great resistance which the water has to overcome in its passage through the strata, the real motive power lying in the thermal contrast and resulting difference of density.[1] This condition greatly extends the field of the subterranean circulation, especially if it be conceded that a difference of density due to a local rise of temperature may take the place of a topographic head as a cause of movement. Synclines, being little subject to fractures opening upward, have been commonly regarded as closed basins, in which, below the drainage level of the district, the water must be essentially stagnant. But it appears now that, in so far as synclines are composed of porous strata which have been exposed at the surface by erosion, and especially if these are overlain by less pervious beds so as to confine the water in a definite channel, they will be traversed by currents of water; and the deeper and more unsymmetrical the syncline the more efficient the circulation will be, at least until the pressure becomes sufficient to close the pores of the rock. Anticlinal folding leads to the formation of cracks gaping upwards, and these may admit water to porous beds which do not actually outcrop. Thus we are led to the conclusion that, other things being equal or apart

[1] Transactions American Institute of Mining Engineers, 23, 217.

from the highly impervious rocks, like the clays, shales, and compact limestones, the conditions are least favorable to a general or definite circulation of the ground water in those portions of anticlines lying below impervious and unbroken strata. This, it may be added, is the general position in which are found not only the chief stores of petroleum and natural gas, which might be supposed to seek the under sides of anticlinal arches in obedience to gravitative influences, but also of salt water (fossil sea-water); that is, water which we have reason to believe from its composition has been in the strata since their deposition on the sea-floor.

If the principle upon which it is here sought to base an explanation of the Sea Mills is sound, it has an obvious and important bearing upon the formation of mineral veins, impregnations, and other forms of subterranean aqueous deposits, and of caverns, or spaces of dissolution. In fact, there appears to be no just ground for limiting the formation of limestone caverns to the superficial or vadose circulation. The chemical activity or solvent power of the water is due largely to the carbon dioxide and oxygen absorbed during its passage through the atmosphere and the *humus* layer; and both this fact and the thermal conditions, heating downward and cooling upward, are obviously favorable to solution by the descending currents and deposition by the ascending currents, especially in their upper courses.

Water may penetrate the earth's crust through open fissures, due to seismic and orogenic movements, and inclined porous strata, under the influence chiefly of gravity, or by seepage along joint, bedding, and foliation planes and through the pores (interstices) of the rocks, in obedience chiefly to capillary attraction. Daubrée and Poiseuille have shown that the subterranean heat probably favors rather than hinders the downward interstitial movement, and hence we may conclude that capillary attraction probably urges the water down to depths below those at which gravitational flow ceases to be a possibility through the closing of the channels by pressure and rock flow. The capillary or interstitial seepage is so slow that the water has ample time to assume the temperature normal to the depth and to exert its full solvent and metamorphic influence upon the rocks, these influences increasing with the temperature and pressure. Under the enormous rock pressures the interstitial water will in part, as shown by the phenomena of artesian and oil wells, be forced into

any fissures or cavities of sensible width that may be open to it, and thus as it rises to levels of lower temperature and pressure contribute of its dissolved minerals to the formation of mineral veins. The water goes down by both seepage and flow, and rises by flow alone; and it must be to the seepage water chiefly that we owe the mineral solutions essential to the formation of the subterranean aqueous deposits, while a gravitational flow is essential to bring the mineral solutions into the zone where the conditions favor deposition.

Although the interstitial water of compact sedimentary rocks, as of other close-grained rocks, may be referred in part at least to seepage, yet below the drainage level, and especially at great depths, it must be in part the water with which the sediments were originally saturated at the time of their deposition (fossil sea-water). In a fissure or system of fissures, or channel of any sort, open enough for gravitational flow and communicating with the surface of the ground, the pressure cannot exceed the hydrostatic pressure due to the depth. In the absence of such an outlet, the water, under the combined influences of capillarity and gravity, may slowly penetrate deeper and deeper, but there can be no true circulation. When, however, a fissure is suddenly opened to a great depth, the imprisoned interstitial water of the surrounding close-grained rocks, whether due to seepage or original saturation, escapes from the rock pressure and wells upward in the fissure, forming mineral deposits more and more freely as it approaches the surface.

In a purely gravitational circulation through a system of fissures or porous strata, whether due to an efficient topographic head or a difference of temperature, the flow will in general be too copious or too rapid to permit of its becoming a concentrated solution of the rock constituents and thus an efficient agent of deposition in its upward course. The solution of the rocks may take place on an extensive scale, as in the formation of limestone caverns, but the resulting solutions are very dilute, and thus incapable in general of subsequent underground deposition. It is the stream coursing along the bottom of a cavern that has given us the cavern itself, but it is the seepage from the roof that has adorned it with the varied stalactitic and stalagmitic formations. Apparently the only conditions favoring simple, non-metasomatic deposition or vein formation by a purely gravitational circulation are where the circulation is very prolonged, profound, or feeble, partaking in the last case somewhat

of the character of seepage. Probably in all deep gravitational circulation seepage water is being constantly added to the current, enriching the solution and rendering subsequent deposition more possible. The upward current has then a dual source — downward flow and downward seepage. But it is in the third case, where the downward flow is entirely wanting and water descending by seepage or interstitial percolation rises in obedience to rock pressures through profound fissures, that deposition is most likely to occur. During its slow progress downward the water has had ample time to become, and may be assumed to be, a saturated solution of some at least of the rock constituents; and hence deposition is imminent from the beginning of its ascent in the fissure through cooling and relief of pressure, the greatest relief of pressure taking place where the water escapes from the rock into the fissure.

From all this the conclusion seems naturally to follow that the deep circulation which is apparently inaugurated in the Sea Mills probably does not lead to vein formation in any part of its course. But it is necessary here to take account of different causes of deposition. Except in the vadose region, as in ordinary caverns, evaporation need not be considered. In cooling and relief of pressure we have simple physical causes, the efficiency of which must vary with the depth. But chemical reaction between the solutions and the rocks through which they flow, tending to the metasomatic replacement of the latter, is more or less independent of depth, varying with the nature of the solutions and the character of the rocks. Metasomatic deposition, it is needless to add, is now generally recognized as a factor of prime importance in the formation of subterranean aqueous deposits and especially of ore deposits. It is not necessary to discuss here the various phases of metasomatism, but it may be noted in passing that one of its chief results has been the replacement of carbonates in the deep region by silica and metallic sulphides derived from still deeper and, probably, in the main, non-sedimentary sources. Metasomatic deposition is not directly dependent upon a concentrated solution, and on this ground it might conceivably accompany such a strong gravitational circulation as is represented by the Sea Mills. The chief difficulty here is that such a circulation must carry to a great depth the oxidizing and carbonating influences of the vadose region, and to overcome these a very prolonged course must be postulated. But the water which passes

downward by interstitial percolation loses during its slow passage through the rocks its free oxygen and exchanges its free carbon dioxide for dissolved carbonates, chiefly alkaline, and is thus well equipped for effecting the deposits and replacements which we later discover in its path.

This outline of the ascension theory of subterranean aqueous deposition may be variously modified; but in the absence of inclined porous strata we cannot dispense with dynamic cracks, and the chief deposits, whether vein, impregnation, or replacement, must take place along or in the upper portions of these and be essentially contemporaneous with a period of seismic or orogenic activity. Hence, in a region of marked and long continued freedom from such activities, like New England, subterranean deposits are probably not forming on a large scale at the present time, and those formed in early ages have been in large part removed by subsequent erosion, for a vein is not so bottomless as a dike.

The deep and localized aqueous circulation represented by the Sea Mills involves, of course, a cooling of the earth by convection, as suggested by Lane,[1] and especially must the isogeotherms be depressed in the vicinity of the descending currents. It is a natural suggestion, therefore, that some of the observed irregularities in the vertical temperature gradients of the earth's crust may find an explanation here. Such an exceptionally low gradient as that recently noted by Agassiz[2] to a depth of 4,800 feet in the Calumet and Hecla Mine would thus indicate a strong and long continued downflow of water,[3] while the abnormally high gradient of the Comstock Lode has already been attributed by Becker[4] to the powerful and long continued ascending current which has given us this notable ore deposit.

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[1] American Geologist, 17, 100.

[2] American Journal of Science, 50 (1895), 503.

[3] Shaler has recently suggested that this abnormally low gradient may be based upon an erroneous determination of the surface temperature.

[4] Monographs United States Geological Survey, 3.

MELTING POINTS OF ALUMINUM, SILVER, GOLD, COPPER, AND PLATINUM.[1]

By S. W. HOLMAN, with R. R. LAWRENCE and L. BARR.

The following melting points are offered as provisional only, but with the belief that they are more reliable than previous data. The absolute values depend in part upon the assumption of 1,072° C. as the melting point of pure gold, the recent determination of Holborn and Wien at the Reichsanstalt. Should that datum, however, be shown to require revision, the validity of the present measurements would not be impaired, but new values of the melting points could be readily computed from them which should be consistent with the better value for gold.

Al.	Ag.	Au.	Cu.	Pt.
660°	970°	1,072° C. assumed	1,095°	1,760°

The pure metals used were of a high degree of fineness, except, unfortunately, the platinum.

The gold contained less than 0.01 per cent. total impurities, these being, if any, probably minute traces of silver and platinum. It was obtained as part of a specially prepared lot from the United States Assay Office in New York, through the courtesy of Professor H. G. Torrey, upon whose authority the above statement is made. The purity was at least as great as the best "proof" metal used at the United States or London mints.

The silver was from the same source and equally pure.

The aluminum was manufactured and given by the Pittsburg Reduction Company, of Pittsburg, Pennsylvania, and was stated by

[1] Presented at a meeting of the American Academy of Arts and Sciences, November 13, 1895.

Mr. Alfred E. Hunt, president of the company, to contain but 0.07 per cent. of impurity, consisting entirely of silicon.

The platinum was the ordinary platinum wire supplied by Carpentier, of Paris, with his LeChatelier thermoelectric pyrometers. It presumably contained $\frac{1}{2}$ per cent. or more of impurity.

The copper was electrolytically produced, and was from the Lake Superior region. It was kindly given by Mr. Maurice B. Patch, of the Buffalo Smelting Company, Buffalo, New York, who stated that it showed by analysis 99.99+ per cent. of Cu, and contained no Ag, As, or S, and only 0.0002 per cent. of Fe.

The Less Pure Metals. — Partly for the purpose of testing the effect of impurities other samples of gold and copper were employed, with the results stated later. These were:

Dentists' Gold. — This was a gold foil employed by dentists, purchased as being of good quality.

Ingot Copper. — This was also from Mr. Patch, of the Buffalo Smelting Company, who gave its analysis as:

Cu	99.825	S	0.022
Ag	0.032	Fe	0.003
As	0.003	O	0.116
			100.001

This was the company's "regular run" of copper.

Commercial Electrolytic Copper. — A sample of commercial electrolytic rolled sheet copper, furnished by a friend, and not assumed to be of unusual purity. It was probably Montana copper.

Commercial Hard-Drawn Copper Wire. — This was from a lot purchased by the Institute for electrical testing purposes, which showed an electrical conductivity of about 0.1440 international ohms per meter-gramme, or 98.3 per cent. referred to Matthiessen's copper.

Method and Apparatus. — The method consists in measuring the thermal electro-motive force of a couple composed of one wire of platinum and the other of a 10 per cent. rhodo-platinum alloy. One junction is immersed in the melting or solidifying metal, and the other surrounded by ice. The wire was that furnished by Carpen-

tier, of Paris (through Queen & Company, of Philadelphia), with the LeChatelier pyrometer.

The emf. was measured in microvolts (international) by the Poggendorff null method, modified for rapid and convenient working. The disposition of apparatus is shown in Figure 1. *B* is a battery of sufficiently steady emf. (two Samson-Leclanché cells in parallel were entirely satisfactory). In direct circuit with this are two water rheostats, *W*, in series; an ammeter, *A*, which was a Weston voltmeter (No. 395) with only the calibrating coil in use; and a "manganene" wire resistance, *a*, *b*, *c*, *d*, divided into sections, each of accurately known resistance. *T* is the thermo-couple, connected through a sensitive galvanometer, *G*, and key to any desired sections of the coil *a*, *b*, *c*, *d*. The water rheostats were of about 100 ohms and 8 ohms, respectively, and the vertical motion of their plungers thus served to give a coarse and fine adjustment to the resistance in the circuit. The current could thus be promptly and closely adjusted. The voltmeter was one of the type having a "calibrating coil," that is, one having a connection by means of which the usual high resistance series coil could be cut out, leaving its resistance about 117 ohms. Any of the Weston voltmeters with a special connection made to effect that result would answer equally well. The voltmeter was preferred to a mil-ammeter, as probably more reliable. The instrument was carefully and repeatedly calibrated throughout its scale by an application of the Poggendorff method, measuring by the Clark cell the drop of potential in a known resistance through which a current was passing in series with the ammeter, and at the same instant reading the ammeter. The calibrations at different times checked at the same point with an average deviation of only a few hundredths of one per cent. A test for temperature error showed a change of but 0.1 per cent. for a change of 15° C.; so that, as

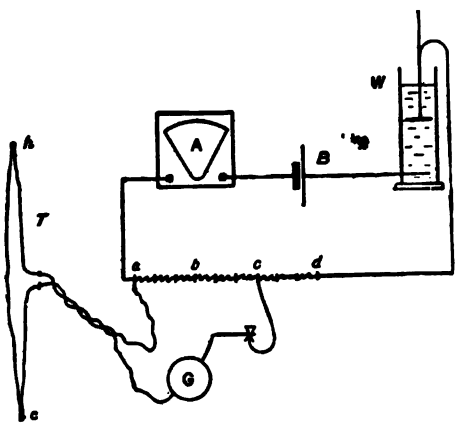

FIG. 1.

the temperature during the work was constant within a few degrees, no correction was needed. The manganene coil, Figure 2, consisted of about 16 feet of No. 20 wire, had a total resistance of about 8.8 ohms, and was divided into nine sections by copper potential wires leading into different points along the coil. These sections were so designed that, by suitably shifting the connections along *a*, *b*, *c*, etc., any thermal emf. which was to be measured could be balanced by a current which would deflect the ammeter to a point between 90 and 140 divisions (readable to tenths), corresponding to currents from 0.006 to 0.009 amperes roughly. The coil was immersed directly in kerosene, and as its temperature coefficient was but 0.001 per 1° C. the correction became very small. The relative and actual resistance (international ohms) of the whole coil and its several sections were repeatedly determined against a standard ohm by the differential galvanometer and checked by a modified Wheatstone bridge arrangement. These data were reliable probably well within $\frac{1}{20}$ per cent. throughout.

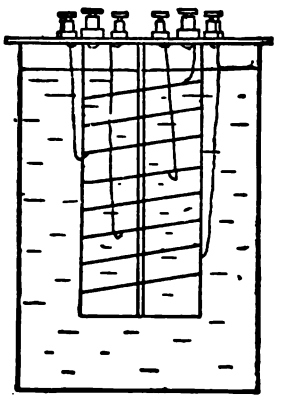

FIG. 2.

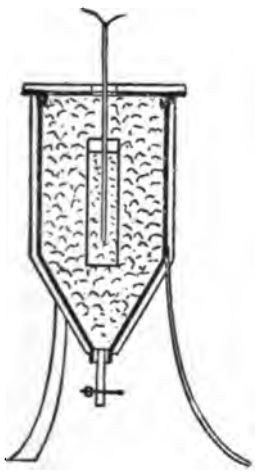

FIG. 3.

In the thermo-couple circuit the sensitiveness necessary in the galvanometer to give the smallest emf. to 0.1 per cent. was easily computed to be only about $7.7 \cdot 10^6$ (mms. defl. at 1 m., per ampere, or d/c). The instrument as actually used exceeded this requirement, averaging about $5 \cdot 10^7$. Its resistance, all in series, was 14.3 ohms.

The cold junction *c* of the thermo-couple was fused together in an oxy-hydrogen flame. The wires, insulated from each other by having one strung through a very fine glass tube, were run down another tube about $\frac{1}{8}$ inch inside diameter and 8 or 10 inches long. This tube was fused together at the bottom and top, as well as at some intermediate points, and when in use was always packed in a double vessel of cracked ice, as shown in Figure 3.

The intermediate junctions from which the copper leads went off to galvanometer and key were soldered. They were kept at an equal temperature by the device of inclosing them in a stoppered glass tube, which was packed with hair felt into a 1-inch hole in a 5-inch cube of cast iron. This arrangement was entirely satisfactory, but seems to possess no material advantage over making the junction of the copper leads with the Pt and PtRh serve as the cold junction, and immersing this in ice, as in Figure 2, except that the latter makes a rather more bulky mass to insert in the ice.

The wires were also fused together at the hot junction, except when this was unnecessary on account of their being immersed in metal. It may be noted here that, as a null method was employed, the total resistance of the thermal circuit, or any variation in it, was without effect other than a corresponding change in sensitiveness.

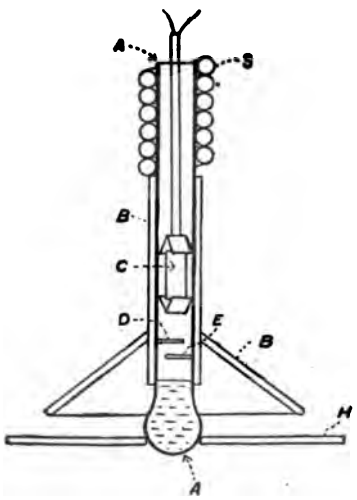

FIG. 4.

As the hot junction was to be immersed in vapor of sulphur as one of the known temperatures, the following apparatus was designed for this purpose. It is substantially the sulphur boiling point apparatus of Griffiths, and is shown in Figure 4. A glass tube, *A*, similar to the Victor Meyer vapor density tube, 16 inches long and with a 2-inch bulb, was provided with an asbestos jacket and hood, *B B*. The upper few inches of the tube were wound with a spiral wire spring, *S*, which rendered this part efficient as a condenser. The top was closed with a layer of asbestos. Two overlapping diaphragms of asbestos were inserted in the tube at *D* and *E*. The couple passed downward through a glass tube to the asbestos tubular hood *C*, which served as an umbrella to shed the dripping cooler sulphur and as a radiation screen. The hood, however, had openings top and bottom for the free circulation of the vapor. An asbestos diaphragm, *H*, upon which the bulb rested, reduced the chances of superheating.

For the melting metals, after trial of several devices, the one shown in Figure 5 (of exactly half size) was settled upon as proving

very satisfactory. The crucible *C* (usually of fire-clay) is supported by blocks *B B* in the double-walled fire-clay furnace *F*. A carbon block, *E*, channeled to fit the crucible, forms its cover, and a carbon diaphragm, *D*, inside the crucible serves to support some powdered carbon shown by the dotted mass. The object of these carbon parts was to prevent oxidation of molten metals, and they proved very effective in the case of aluminum, silver, and copper. *G G* was an asbestos diaphragm, supporting a non-conducting layer of fibrous asbestos, *A A*. The temperature was controlled by the blast lamp, *B*. The clay crucible was 1 inch in diameter outside, and the amount of metal employed ranged from 11 grammes (gold) to 35 grammes (copper). Large amounts might be advantageous, but with 30 to 35 grammes it was easily possible to obtain a constant indication for five minutes during the melting or solidifying of copper. No difficulty whatever was experienced with this arrangement with silver, gold, or copper. With aluminum, however, a peculiar action occurred, the cause of which in the time available for investigation could not be determined beyond doubt. The phenomenon was that, after a few minutes of constant temperature at the melting point, the indication of the thermo-couple fell off with increasing rapidity. On withdrawing the couple, cleaning it, or clipping it off and restoring it to place, the melting metal meanwhile being untouched, the indications returned to their original high value. The apparent explanation was the formation of a slag between the wires, but this was not entirely satisfactory. The use of a plumbago crucible in place of the clay and an entirely fresh lot of aluminum did not remove the phenomenon, and gave the same ini-

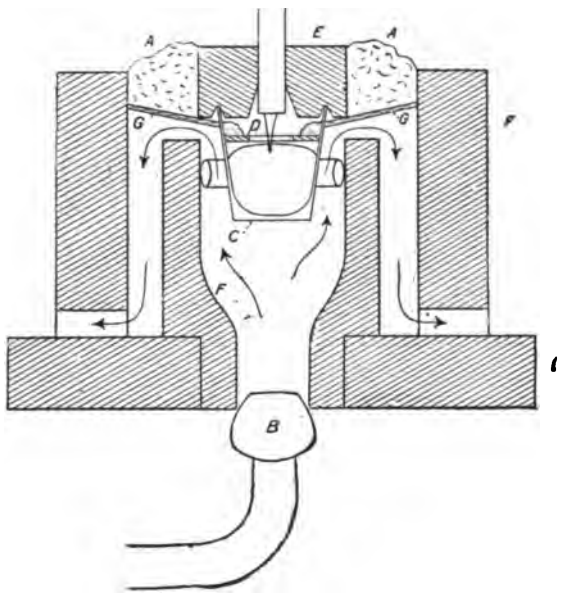

FIG. 5.

tial readings, which it could not be doubted were the ones corresponding to the melting point. The fusion of the aluminum was, however, the least sharply defined of all the metals used.

The fusion of platinum was, of course, differently effected. For this the two wires of the couple were laid close together on a piece of lime. An oxy-hydrogen flame was then directed upon their ends, and the platinum fused into a globule which with care could be made to travel slowly up the wire. There was no difficulty in obtaining steady temperatures for a sufficient period to make the necessary readings, and check results to 0.1 per cent. were obtained on different days.

The galvanometer, keys, coils, and all junctions of dissimilar metals were, so far as possible, covered with boxes of wood, pasteboard, or asbestos to maintain uniformity of temperature and thus minimize local thermoelectric disturbances. With this precaution no sensible trouble from that source was experienced.

The procedure is as follows: To take the observation for vapor of sulphur, for instance, the hot and cold junctions are exposed as described. After a sufficient time the main circuit is closed, the thermal circuit is connected to a suitable part of a, b, c, d, and the rheostats, W, are adjusted until on pressing the key no deflection occurs in the galvanometer, G. At this instant A is read, which gives the current c in the main circuit. The adjustment is disturbed and remade a number of times, and the resulting readings should check to the nearest tenth of a division of A, provided the metal has reached a steady state of temperature.

By this adjustment the drop of potential cr, due to the current c amperes in the part r ohms of the resistance a, b, c, d, spanned by the thermal circuit, is made equal to the total resultant emf. in the thermal circuit. The latter, which will be denoted by $\Sigma^t_c e$ or $\Sigma^t_o e$, is the algebraic sum of the thermal emf. proper of the junction, of the Thomson emf. in the wires, and of any "stray" or local thermal emf. in the circuit. The last was found to be negligible throughout the work.

To observe the melting point, the furnace containing the metal is heated more or less rapidly until the melting point is approached. The blast lamp is then adjusted to give a slowly rising temperature. The thermal circuit, with the couple previously fused into the metal, is connected to a suitable section of a, b, c, d; the rheostats are con-

tinually adjusted for zero deflections of the galvanometer, G, and the corresponding readings of A are taken. These will show gradually increasing values, but the rise will presently be interrupted by a series of constant readings, after which the readings will again steadily increase. This period of constant or nearly constant readings of A is that in which the latent heat of fusion is being absorbed, and its duration is frequently several minutes. The temperature at that time is, of course, that of the melting point. The reverse process, starting with the metal in a molten state and cooling it gradually, shows a similar period of solidification.

No difference was discovered between the ascending and descending readings when a sufficient amount of the metal and a slow rate of heating and cooling were employed. With small amounts the steady reading was more or less masked by phenomena which were clearly due to inequality in distribution of temperature throughout the mass of mixed liquid and solid metal. In the case of aluminum, however, something more than this irregularity was observed, as elsewhere stated, but the time at command did not permit a study beyond the point of satisfying ourselves that the point observed was unquestionably the true melting point.

This work was chiefly done as the thesis work of Messrs. Lawrence and Barr. The efficient assistance of Mr. C. L. Norton contributed materially to its progress and success.

The computation of temperatures t from the observed electro-motive forces Σe involves a knowledge of the function connecting the two, *i.e.*, of the function,

$$\Sigma_o^t e = f(t), \quad \text{or } t = F(\Sigma_o^t e).$$

This problem has been elsewhere [1] discussed by one of the authors of this paper.

In that article two interpolation formulæ were developed. They were respectively of the following forms, applying to the case where one junction of the couple is kept at 0° C., and the other is at any other temperature t C., or $\tau = t + 273°$ absolute m and n are constants, different for the two expressions; $\Sigma_o^t e$ denotes the resultant

[1] Holman: This journal, vol. viii, p. 353.

thermal emf. of the circuit, viz., that which is the object of direct measurement. The first, called the exponential equation, is

$$\Sigma_o^t e = m\tau^n - \beta, \text{ where } \beta = m\tau_o^n = m(273)^n.$$

The second expression, called the logarithmic equation, is

$$\Sigma_o^t e = mt^n, \quad \text{or } \log \Sigma_o^t e = n \log t + \log m.$$

Both formulæ have been applied to the data of the present investigation given in Table I, with results shown below. The Avenarius formula has also been applied for purposes of comparison.

To evaluate the constants m and n of the exponential equation (for method consult the paper referred to) it is necessary to have values of $\Sigma_o^t e$ at three known temperatures. Of these, however, one may be $\Sigma_o^t e = 0$, at $\tau = 273°$, *i. e.*, with both junctions in ice. It therefore remains to fix upon two other temperatures between which to interpolate, or, in other words, two other temperatures which shall be assumed as known. In looking over the ground it seemed that the boiling point of sulphur being so high and so accurately determined by Callendar and Griffiths [1],

$$444°.53 + 0.082\ (H - 760)$$

was preëminently one of these points. The other must be much higher, and the melting point of pure gold seemed to be almost, if not quite, the only one upon which reliance could be placed.

Apart from freedom from oxidation and its conveniently high point of fusion, gold seemed the more suitable, because its melting point had recently been so carefully measured by Holborn and Wien, and because the metal could be obtained of the necessary purity. Add to these considerations the fact that its melting point in a state of at least fairly high purity has been measured by more experimenters than that of any other high melting metal, so that it serves as an excellent connecting link between their work, and we have claims which no other substances can at present offer. The fusion point of gold was therefore chosen as the second reference or calibration temperature. As to the figure to be assumed as the melting point of gold there is room for difference of opinion. The claims of the work of

[1] Callendar and Griffiths: Phil. Transac., **182**, 119, 157 (1891).

Holborn and Wien, supported to some extent by considerations advanced by Barus[1], lend much weight to the conclusion that Violle's value of 1,035° is considerably too low. Granting this, and in the absence of sufficient basis for the assignment of weights to the work of divers other investigators, the simplest and best step seemed to be to adopt provisionally, without modification, Holborn and Wien's value,

$$1{,}072°.$$

These two points settled upon, the constants m and n could be computed as elsewhere described and the equation transposed to deduce other values of t from observed values of $\Sigma^t_o e$. Representing $m\tau^n$ by β, a constant, the equation for the temperature as a function of $\Sigma^t_o e$ takes the form,

$$t = \sqrt[n]{\frac{\Sigma^t_o e + \beta}{m}} - 273,$$

which is, of course, easily solved by logarithms.

The data given in Table I yield the values $m = 0.3901$, $n = 1.488$, $\beta = 1.645$, in international microvolts and degrees centigrade, so that

$$\Sigma^t_o e = 0.3901\ \tau^{1.488} - 1{,}645, \text{ or } t = \sqrt[1.488]{\frac{\Sigma^t_o e + 1{,}645}{0.3901}} - 273.$$

From these the temperatures of Column 6 have been computed.

The constants of the logarithmic formula have been computed from the same data for sulphur and gold, the method being sufficiently obvious. The equation becomes,

$$\Sigma^t_o e = 2.49\,655\ t^{1.2563}.$$

The corresponding melting and boiling points are given in Table I, Column 7.

Substitution of the same data in the Avenarius equation yields,

$$\Sigma^t_o e = (t_k - t_c)\ \{9.7335 + 0.00\,484\,49\ (t_k + t_c)\}.$$

[1] Barus: American Journal of Science, 48, 336.

Provisional Values of Melting Points.

In the paper referred to it has been shown that the logarithmic expression fitted the Barus comparisons of the irido-platinum couple with the air thermometer within the limits 400° to 1,200° C. with no sensible systematic error; second, that the exponential equation similarly fitted the Holborn and Wien comparison of the rhodo-platinum couple with the air thermometer within the same limits; third, that the exponential equation diverged systematically, although slightly, from the Barus data, and the logarithmic from the Holborn and Wien data, by about equal and opposite amounts both inside and outside these limits, but much more markedly between 0° and 400° than at higher points.

Inspection of Columns 6 and 7, Table I, will show that the computed boiling points of water and naphthalin by the exponential and logarithmic equations depart widely from the known temperatures in opposite directions by about equal amounts, and in the directions according with the departures from the Barus and Holborn and Wien data. Also that the differences between the computed melting points intermediate between sulphur and gold differ but slightly by the two formulæ, thus confirming the former conclusions. It is obvious, therefore, that although either of the two formulæ would yield fairly good interpolations for Al, Ag, and Cu, yet that a mean between the two would probably quite nearly offset against each other the systematic errors of the respective equations. This is also true in the dangerous process of extrapolation for the platinum melting point, where the chances of error in the result seem to be probably very much reduced by averaging. The means of the melting points computed by the exponential and logarithmic equations are therefore regarded as the nearest available approximations, and the round numbers of Column 9 are adopted as provisional values to represent the results of the work.

Comparison of the results of the Avenarius formula, Column 5, will show that they depart widely from the others in the direction which would have been anticipated from the conclusions of the previous paper, thus further strengthening those inferences.

In addition to the foregoing, the melting points of three other samples of copper and one other of gold were measured. The gold was dentists' gold "foil," purchased in Boston. This is usually classed as "very nearly pure," but its analysis is not known. No special interest, therefore, attaches to it beyond the indication that

it gives of the sign and order of magnitude of the error (about —4°) which would be introduced by the use of such gold in the calibration of the LeChatelier pyrometer[1] or in similar ways. The melting point was found to be 1,068°.

TABLE I.—MELTING POINTS.

Date.	Substance.	Σe. Microvolts.	Temperatures.					
			Assumed as correct.	From Avenarius equation. t_a.	From exponential equation. t_e.	From logarithmic equation. t_l.	$\frac{t_e + t_l}{2}$	Provisional values.
3—?	H_2O	885.8	99°.64	.....	.....	.....	.....	.....
4—10	H_2O	890.4	100.57	.....	.....	.....	.....	.....
		888.1	[100.1]	87°.4	91°.7	107°.3	99°.5	.....
3—15	$C_{10}H_8$	2,213	218.3	.....	.....	.....	.....	.....
3—23	$C_{10}H_8$	2,224	218.9	.....	.....	.....	.....	.....
3—25	$C_{10}H_8$	2,216	218.2	.....	.....	.....	.....	.....
		2,218	[218.5]	206.6	211.4	222.4	216.9	.....
3—?	S	5,287	444.7	.....	.....	.....	.....	.....
3—22	S	5,289	445.2	.....	.....	.....	.....	.....
3—29	S	5,287	444.5	.....	.....	.....	.....	.....
		5,288	[444.8]	.....	.....	.....	.....	.....
4—24	Cu	16,463	.....	1,095	1,095	1,096.5	1,095.5	1,095°
4—29	Au	16,002	[1,072]	.....	.....	.....	.....	[1,072]
4—29	Ag	14,093	.....	975	972	969	970.5	970
5—2, 3	Pt	30,313	.....	1,695	1,735	1,783	1,759	1,760
5—3	Al	8,638	.....	665.5	662.5	656.2	659.4	660

Avenarius, $\Sigma_o^t e = (t_2 - t_1)\ \{9.7335 + 0.00\ 484\ 49\ (t_2 + t_1)\}$.

Exponential, $\Sigma_o^\tau e = 0.3901\ \tau^{1.488} - 1{,}645$.

Logarithmic, $\Sigma_o^t e = 2.49655\ t^{1.2563}$.

[1] Holman: Calibration of the LeChatelier Thermo-electric Pyrometer, Technology Quarterly, 1895.

The four coppers yielded the appended results:

TABLE II.

$\Sigma^{t}_{0}e$. Microvolts.	Melting points. t.	Purity of metal.	Description.
16,463	1,095°.0	99.99 +	Electrolytic. Probably Lake Superior Copper, Buffalo Smelting Company.
16,448	1,094°.3	99.83	Ordinary Ingot. Same source.
16,456	1,094°.7	Unknown.	Electrolytic. Probably from Montana.
16,446	1,094°.2	Unknown.	Commercial Hard-Drawn Wire from Washburn & Moen Company. Sp. Elect. Conductivity (referred to Matthiessen value), 98.3 per cent.

The concordance of these results on various coppers, together with the completely satisfactory behavior of the metal in fusion and the ease and cheapness of obtaining the metal of a very high grade of fineness, suggest the decided availability of copper in a direct study of high temperatures or melting points by the gas thermometer. A large mass of the metal could be employed and a constant and uniform temperature for a protracted period thus secured for the bulb of the gas thermometer, or for other apparatus immersed in the molten or solidifying material. There are unfortunately too few substances which fulfill even these requirements. An added merit lies in the nearness to the gold melting point, enabling the two to be satisfactorily connected by some means of relative measurement.

It also appears that the use of good commercial copper would introduce sensibly less error (3° less) into the calibration of the Le-Chatelier pyrometer than the use of the "dentists' gold" above tested, which is as good metal as would readily be obtained in the market by most observers.

Reliability of the Results. — The points involved are:

Instrumental errors.

Purity of the metal.

Was the observed point the real melting point?

Validity of the interpolation equation.

Error in the assumed melting point of gold and boiling point of sulphur.

The investigation was planned and the apparatus arranged with the intention of reducing the combined instrumental errors below one tenth of 1 per cent. in the measurement of Σe above 200° C. Tests, check measurements, and a discussion of the sources of error, unnecessary to detail here, have given satisfactory demonstration that an even higher accuracy than this was attained. As far, therefore, as constant or variable instrumental errors are concerned it is believed that no error beyond 0°.5 to 1° C. exists in the results, while probably this estimate is large.

The error from impurities must have been exceptionally small, as the analyses of the metals indicate. Some impurities from alloying with the platinum and rhodium of the thermo-couple must have entered during the experimenting, but as results at different stages of the work checked those obtained upon the first use of the metal, and as renewals of the metal made no difference in readings beyond the limits of other variations (about 5 parts in 10,000), the error from this source must have been negligible.

In the case of platinum the metal at command was unfortunately not of known composition, nor was it possible at the time to obtain any whose purity was known. An analysis of the wire used may, perhaps, be obtained later, and it is hoped to carry out further measurements with the better platinum now obtainable through the recent advances made in its manufacture in Germany and England.

The aluminum was of very high grade, but it is thought that still better may be obtained, and the peculiar occurrence attending its melting point measurements should be further investigated.

The actual effect of the small impurities cannot be numerically estimated, but must have been inconsiderable except for platinum, where the error probably has the positive sign.

As to the third point, there was no reasonable doubt left in the minds of the observers that the observed temperatures were sensibly the melting points. Except as noted for aluminum, the readings with rising and falling temperatures did not differ by more than 1 part in 1,000. Also entirely independent observations on separate days, and with renewals of the metals in some cases, were equally concordant. The average difference was much less than the error of reading the ammeter. As an example of the concordance, and at the same time showing the homogeneity of the thermo wire, three calibrations in sulphur will be quoted, viz.:

TABLE III.

Date.	$\Sigma^{t}_{\sigma}\varepsilon$. Microvolts.	Computed temperature of sulphur.	$\Sigma\varepsilon$ reduced to 445°.
March	5,287	444°.73	5,290
March 22	5,289	445°.18	5,287
March 29	5,287	444°.53	5,293

Between these observations a considerable length of the wires was necessarily clipped off. Reduced to a common temperature of 445°.0, the maximum difference is but 6 microvolts in 5,290, or 0.11 per cent., while the average deviation of a single observation is but 0.02 microvolts, or 0.04 per cent., and of the mean but $0.02/\sqrt{3} = 0.012$ microvolts, or 0.024 per cent. At higher temperatures the discrepancy was even smaller.

TABLE IV.

Authority.	Date.	Method.	Metals.				
			Al.	Ag.	Au.	Cu.	Pt.
Lawrence and Barr . . .	1895	Th-el.	660°	970°	1,072°	1,095°	1,760°
Violle	1879	Sp. Ht.	...	954	1,035	1,054	1,775
Ledebur	1884	Sp. Ht.	...	960	.....	1,100	.....
LeChatelier	....	Th-el.	635	...	[1,035]	.....	.....
Callendar	....	.....	...	[945]	1,037	.....	.....
Erhard and Schertel . .	....	.....	...	954	1,075	.....	.....
Barus. By log equation [1].	1894	Th-el.	641	985	1,090	1,095	1,783
Barus. By Equation 3 .	....	.....	...	986	1,091	1,096	1,757
Holborn and Wien . . .	1892	Th-el.	...	968	1,072	1,082	.....
Mean of independent absolute measurements, *i. e.*, excluding L. and B., LeC., C. . . .			641	964	1,068	1,083	1,779

N. B. — Values in brackets [ ] are those assumed by the observers, and upon which their other values depend to a greater or less extent.

[1] See discussion by Holman, this journal, Vol. viii, 353.

The validity of the interpolation formulæ has been already discussed. A statement of the extreme error which may have been introduced into the results by this source should, however, be added. This is believed to be for aluminum less than ± 2°, for silver less than ± 2°, for copper less than 0°.5, for platinum less than 10°.

Comparisons with the temperatures computed by the Avenarius equation show errors by the latter to be about 1.5 times as great for water and naphthalin, and of the same signs. It is, therefore, much less reliable, especially for the platinum temperature, and no weight is attached to its results.

Melting Points by Various Authorities. — A collection of these is given in Table IV. Except in the case of the Barus data, the results are set down directly as given by their authors. A further discussion of them with reference to purity of metals used and the characteristic errors of the methods employed would doubtless prove instructive, and might partly remove or account for some of the apparent discrepancies. This task may perhaps be undertaken later.

ROGERS LABORATORY OF PHYSICS, M. I. T.,
Boston, October, 1895.

REDUCTION OF NITRATES BY BACTERIA AND CONSEQUENT LOSS OF NITROGEN.

By ELLEN H. RICHARDS, A.M., and GEORGE WILLIAM ROLFE, A.M.

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In the course of experiments upon the cycle of nitrogen in aqueous solution under different conditions, it was observed that in some cases a disappearance of nitrogen occurred for which no theory seemed to satisfactorily account. At length a series of tests was made by several consecutive classes of students, which, although liable to irregularities, as are all results obtained by inexperienced workers, were so far conclusive as to encourage further investigation, and two years later one of the instructors carried out a number of confirmatory tests, the results of which are given combined with the rest. It remained for us to complete the investigation and establish the point in question.

It has been repeatedly proved [1] that the cycle of nitrogen in natural surface waters is (1) albuminoid ammonia, (2) free ammonia, (3) nitrites, (4) nitrates, (5) again, albuminoid ammonia; but when feeding nitrates together with organic material to hasten growth it was observed that *nitrites* were the first and only products, and that they soon disappeared. The problem was, What became of the nitrogen, and under what conditions did this disappearance take place?

The nitrates obviously were not reduced to ammonia, although we know that by many chemical and electrical processes this change is quite possible. Neither was this loss of nitrogen from the solution an apparent one only, as was first suggested, due to defects in our analytical methods. The results of the Kjeldahl process did not include the missing nitrogen even in presence of a zinc-copper couple. The general thought, moreover, seems to be against the probability of such loss.

The data herein tabulated represent investigations made with twenty-five or more solutions, the majority of which were so prepared as to typify the condition of a water polluted with decaying organic matter and at the same time containing nitrates. Such a

[1] Among others, see the numerous papers on the purification of waters in the Reports of the State Board of Health of Massachusetts.

solution could be obtained by the admixture of fresh sewage with its purified effluent. We may for convenience allude to these solutions as sewages, but wish it borne in mind, however, that they differ from a mixture of ordinary town sewage in three important characteristics — low mineral content, absence of urea, and presence in most of a small quantity of sugar; moreover, the organic matter at the outset was not as advanced in decomposition as that of even very fresh sewages. The mixture was originally designed to furnish a solution in which at the end of a given time there should be no dissolved oxygen.

The city tap water was used in the preparation of most of these solutions. Nitrates were furnished by potassium nitrate. With one or two exceptions, to be mentioned, fresh milk, in the proportion of one cubic centimeter to a liter, gave the necessary organic matter. Taking the average casein content of milk as 3.4 per cent., the theoretical total ammonia possible, provided none resulted from reduction of the nitrate, was therefore about 0.71 parts per 100,000.

As will be seen by the tabulated data, the general characteristics of the solutions in their successive stages of decomposition were practically identical, the principal variant being in time.

The white turbid solution quickly turned gray, became exceedingly offensive in odor, and evolved considerable gas. This condition reached its most pronounced stage in from four to ten days. The solution then began gradually to lose its turbidity, the evolution of gas practically ceased, and green growth began to appear, usually at the bottom. This growth rapidly increased on the glass until the entire bottle was thickly coated with green, the offensive odor meanwhile disappearing.

Turning to the chemical analyses, we find the following well-marked periods corresponding to these changes: (1) A rapid disappearance of nitrates, usually less than 10 per cent. remaining at the end of three days; (2) a correspondingly rapid increase in nitrites, (3) these usually reaching a maximum two or three days later, and (4) then in turn rapidly disappearing; (5) a slight reappearance of nitrites following the green growth; (6) gradual reappearance of very small quantities of nitrates.

During all these changes the total nitrogen obtained as ammonia remained fairly constant,[1] while the tests for free and albuminoid am-

[1] Discrepancies in individual analyses are considerable, but this is to be expected, for, aside from the inexperience of the students, it is very difficult to get a representative sample from such large bottles thickly coated with a tenacious growth.

monia show a general conformity to the laws governing the cycle of nitrogen changes already referred to in this paper and fully discussed in a previous publication.[1] Stages (5) and (6) can be interpreted in the same way.

This conformity is also manifest in the tests made of solutions made with milk without the addition of nitrate. Moreover, the fact is at once established that the nitrate rapidly changes to nitrite, and almost as rapidly disappears. We do not, however, find practically any of this nitrogen of the nitrate revealed to us by our tests for ammonia. In fact, it not only does not conform to the laws of change observed in surface waters, but, as far as our examination of the solution goes, it has quite disappeared. At the same time the nitrogen from the milk proceeds in the regular cycle, at any period of which the various tests give a sum total of nitrogen approximating closely to that obtained from the original fresh milk solution. Tests made many months later confirmed the result.

The following tabulated data from tests on milk solutions made as described — one with nitrate, the other without — illustrate these nitrogen transformations clearly:

A. { Milk, 8 cc. / City Water, 8 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
March 13	...	.001[2]	....	....	000	.004
March 16	3	.002	....	....	000	....
March 17	4	.015	....	....	000	.007
March 18[3]	5	....	....	....	000	.035
March 23	10	.201	....	....	000	.010
March 30	17	.275	....	....	000	.020
April 6	24	.360	....	....	000	....
April 13	31	.332	.240	....	000	.032
April 20	38	.200	.140	....	000	.008

[1] "Nitrification and the Nitrifying Organism," by E. H. Richards and E. O. Jordan, Exp. Investigations by the Mass. Board of Health upon Purification of Sewage. Part II, 1890, p. 872.

[2] All figures express parts per 100,000 unless otherwise specified.

[3] On this date a little soda was added to the solution, which was quite acid.

Green Growth.

April 29	47	.180	.160	....	...	.002
June 22	101	.003	....	.700	...	000

B. { Milk, 8 cc. KNO_3, 2.50. (N = 4.33 parts per 100,000.) City Water, 8 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
March 13	½	000	.330	....	000	1.500
March 16	3	.079	....	....	2.280	....
March 17	4	.159	....	....	3.040	.060
March 18	5	.216	....	....	1.600	.070
March 19	6	.330	....	....	....	....
March 20	7	.386	....	....	.420	....
March 23	10	.429	....	....	.050	....
March 30	17	.555	....	....	.009	.090
April 6	24	.680	....	....	.100	....
April 13	31	.320	.080	....	.444	....
April 20	38	.018	.110	....	....	....
April 25	42	....	....	....	.540	.080

Green Growth.

April 29	47	.009	....	....	.500	.075
May 2	50	.005	.251	.545	.333	.020
May 5	53	....	....	....	.333	....
May 13	61	....	....	....	.286	.012
June 22	101	....	....	....	.0002	....

Green growth was first noticed in both solutions on April 27.

In case of Solution A, where no nitrates were added, we can find no evidence that nitrites are formed from the decomposition and oxidation of the organic matter. Solution B, containing nitrates originally, on the other hand, shows two remarkable facts — practically the complete reduction of this nitrate to nitrite in less than four days, and the almost complete disappearance of the nitrite a few days later. After the green growth appears the nitrogen passes through the normal life-cycle, the ammonia figures declining as those of the oxidized nitrogen increase.

The tests on Solutions 3 and 4, given below, in general show similar results. It will be noted that the reduction progresses equally in both solutions, but that as soon as the smaller store of nitrate in Solution 4 is exhausted the resulting nitrites *totally disappear in about six hours.* Unfortunately, no tests were made on Solution 3 during the critical fifth and sixth days, so that the time of complete reduction is not exactly established. It will be seen, however, that the evidence is strong that it occurred on the afternoon of May 10. The relatively slower reduction of these solutions may be due to their frequent disturbance during the sampling for tests. The time of reduction, as we have said, is variable. Solutions started in March and April apparently show a greater rapidity of decomposition than those of June and July.

3. { Milk, 8 cc.
KNO_3. (N = 4.33 parts per 100,000.)
City Water, 8 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
May 4, A.M.	..	.044	.270	....	000	4.200
May 4, 4 P.M. . . .	..	....	....	....	.003	....
May 6, A.M.	2	.068	.248	....	.400	....
May 7, A.M.	3	....	....	....	1.080	.080
May 7, 4 P.M. . . .	..	....	....	....	2.000	....
May 8, A.M.	4	....	....	....	2.182	.050
May 11	7	.112	.294	.710	.900	.012
May 20	16	.384	.169	....	000	.003

Green Growth.

May 28	24	....	....	....	.003	.002
June 4	31	....	....	....	.003	.002
June 22	49	.002	....	.830	.001	000
1892. February 27	..	.010	.340	.744	000	....
1893. January 2	..	....	....	....	....	.150

4. { Milk, 8 cc. KNO_3. (N = 1.00 parts per 100,000.) City Water, 8 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891. May 4, A.M.	..	.032	.252	.605	000	1.000
May 6, 4 P.M. . . .	2	.064	.294	....	.400	....
May 7, A.M.	3	....	....	....	1.080	.046
May 7, P.M.	..	....	....	....	000	....
May 8	4	....	....	....	.0002	000
May 9	5	.080	....	....	.....	....
May 11	7	.024	.300	.710	.0001	000
May 20	16	.240	.202	....	.0001	000

Green Growth.

May 28	24	....	....	....	.0001	000
June 4	31	....	....	....	.0003	000
June 22	49	....	....	....	000	.002
1892 June 29	..	....	....	.550	.....	....

Solution No. 3 continued to support a vigorous growth of algæ for over three years. On February 6, 1894, a Kjeldahl test gave .640 parts of ammonia in 100,000. Microscopical investigations

showed that organisms were present in the following numbers per cubic centimeter of solution:

Cosmarium,	44,000.	*Protococcus,*	42,000.
Raphidium,	3,100.	Masses of Zoöglœa,	2,800.
Scenedesmus,	23,000.	Infusoria (Monas),	250.

Taking as a commonly accepted fact that these nitrogen transformations which we have discussed are the result of *life* processes, presumably those of bacteria, several questions at once suggest themselves: Can these organisms live on nitrates alone? If not, were we to increase the organic matter present, as the milk, could we make their forces more energetic? Would these organisms thrive on all kinds of nitrogenous organic matter equally well as on milk? The following data were therefore collected. Solution 7, containing no organic matter other than that naturally present in the water, shows that reduction takes place very slowly and incompletely. Although the organisms were present, evidently some necessary food, such as that in milk, was lacking. The solution remained clear and free from odor during the month or more that this investigation was carried on.

7. { KNO_3. (N = 4.00 parts per 100,000.)
{ City Water, 2 liters.

Date.	Age — Days.	Nitrogen as Nitrites.	Nitrogen as Nitrates.
1891.			
May 13	..	.....	4.000
May 15	2	000	.....
May 18	3	000	.....
May 20	7	.0004	.....
May 28	15	.0006	4.000
June 22	40	.0025	2.000

Solutions 5 and 6 show the effect of increase of organic matter by use of more milk.

There is manifestly more rapidity of reduction; at the same time this increase of energy is not proportional to the food supply, showing that, while the latter has a marked influence, there are other limiting conditions.

5. { Milk, 6 cc.
KNO$_3$. (N = 4.00 parts per 100,000.)
City Water, 2 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
May 4	..	.080	....	....	.....	....
May 6, A.M.	2	....	....	....	.526	1.00
May 6, P.M.	..	....	....	....	2.182	....
May 8, A.M.	4	....	....	....	.0003	....
May 8, P.M.	..	....	....	....	.0002	000
May 9, A.M.	5	.080	....	....	.....	....
May 11	7	....	....	....	000	000
Green Growth.						
May 28	23	....	....	....	.333	.005
June 4	31	....	....	....	.364	.010

6. { Milk, 10 cc.
KNO$_3$. (N = 4.00 parts per 100,000.)
City Water, 2 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
May 4	..	.092	....	....	....	....
May 6, A.M.	2	....	....	....	.741	....
May 6, P.M.	..	....	....	....	....	.073
May 7, A.M.	3	....	....	....	3.243	....
May 8, A.M.	4	....	....	....	000	....
May 8, P.M.	..	....	....	....	000	000
May 9, A.M.	5	.080	1.500	....	....	....
May 11	7	.666	1.232	....	000	000
Green Growth.						
May 29	25	....	....	....	000	000

Green growth was first noticed in No. 5 on May 22, in No. 6 on May 26.

Aëration of milk solutions by means of aspirators produced no difference in their behavior other than a slight retardation of the reducing action. Evidently the air could not be retained long enough by the solution to be of any use to the organisms. This is conformable with the results obtained by Dr. Drown on the aëration of natural waters.[1]

II. { Milk, 8 cc. / KNO_3 Solution, 80 cc. (N = 4.00 parts per 100,000.) / City Water, 8 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
June 23	..	....	.355	.500	000	4.000
June 24, 12 M. . . .	1	....	....	....	.007	.....
June 24, 5 P.M. . . .	..	....	....	....	.022	.....
June 25	2	.112	....	....	2.272	1.000
June 30	7	.236	....	....	4.000	.....

II A. Same solution as II, but aërated continuously.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
June 23	..	....	.355	.500	000	4.000
June 24	1	....	....	....	.0025	.....
June 25	2	....	....	....	1.600	2.000
June 30	7	.258	....	....	4.000	.....

Another solution was made up in a precisely similar way as No. II, except that a portion of Solution No. 3 was used in its preparation, with the intention of seeding it with organisms already developed.

[1] "Effect of the Aëration of Natural Waters," by Dr. Thomas M. Drown, in the Twenty-Third Annual Report of the State Board of Health of Massachusetts. Also, page 479 of the Twenty-Sixth Report of the same Board in an article on "Filtration of Sewage," by George W. Fuller.

12. Milk, 8 cc.
KNO_3 Solution, 80 cc. (N = 4.00 parts per 100,000.)
City Water, 7.5 liters.
Solution 3, .5 liter.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
June 23	..	....	.303	.700	.0001	.....
June 24, A.M. . . .	1	....	....	....	.0002	.....
June 24, 5 P.M. . . .	..	....	....	....	.0018	.....
June 25	2	.048	....	....	1.740	2.000
June 30	7	.004	....	....	4.000	.....

12 A. Same solution, except aërated continuously.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
June 23	..	000	.303	.700	.0001	.....
June 24	1	....	....	....	.0007	.....
June 25	2	....	....	....	.800	3.000
June 30	7	....	....	....	4.500	.....

We have so far made but few investigations as to the nature of the food required by these organisms.

Solutions have been made with one cubic centimeter of blood per liter instead of milk. These solutions changed but little in appearance even after a month's standing. The chemical tests show that the reduction proceeded very slowly; in short, the organisms present, if they thrived on the blood, did not apparently obtain oxygen by tearing apart the nitrate.

Solution 8, containing in addition to the blood four parts of sugar per 100,000, showed no marked difference in behavior or reduction of nitrate, although the tests show slightly more nitrite.

1. { Blood, 8 cc.
   { KNO_3. (N = 4.00 parts per 100,000.)
   { City Water, 8 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
May 4	..	.052	.458	3.11	000	4.000
May 4, 4 P.M. . . .	..	....	....	....	.0003	.....
May 6	2	.072	....	....	.0003	4.000
May 8	4	....	....	....	.0075	.....
May 9	5	.560	....	....	.003	.....
May 20	16	1.454	....	....	.013	2.500
May 28	24	....	....	....	.020	.....
June 22	49	....	....	....	.040	1.200

8. { Blood, 2 cc.
   { KNO_3. (N = 4.00 parts per 100,000.)
   { Grape Sugar, .080 gram.
   { City Water, 2 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
May 13	..	....	....	....	000	4.000
May 15	2	....	....	....	.0002	.....
May 18	5	....	....	....	.136	.....
May 19	6	....	....	....	.200	.....
May 20	7	....	....	....	.200	3.500
May 28	15	....	....	....	.190	.....
June 22	40	....	....	....	.028	1.200

These solutions showed no green growth for many months, and at no time was this growth anything but scanty.

A few solutions were prepared from materials in themselves practically sterile, distilled water and evaporated milk. These solutions were inoculated with liquid from old solutions; one with a solution

originally made with milk, another with a blood solution, a third with a solution containing milk and glycerine (to be described later), while the fourth contained no admixture of old solutions. Bacteriological cultures were made from these solutions from time to time. The tables show the immense multiplication of these organisms, and also give the results of some Kjeldahl tests at the end of twenty-two days, which, while they undeniably show that the original total ammonia figures have not changed perceptibly, emphasize the difficulty of getting exact representative samples from the bottles, a trouble already referred to. The figures for the oxygen consumed of Solution 13 are also instructive, and will be referred to later.

13. { Milk diluted from evaporated milk, 8 cc.
{ Distilled Water, 8 liters.

Date.	Age. Days.	Ammonia.			Oxygen Consumed.	Bacteria per cc.
		Free.	Albuminoid.	Total.		
1892.						
March 3	..	.016	.356	.696	4.326	104
March 4	1	....	....	....	2.802	3,000
March 5	2	....	....	....	2.348	.....
March 7	4	....	....	....	2.307	.....
March 15	12	....	....	....	{ 1.081 { *f*.589	150,000
March 25	22	.240	{ .206 { *f*.072	{ .630 { *f*.150	.....	.....
				{ .652 { *f*.384		

f = filtered.

14. 2 liters of same solution, but with addition of 50 cc. of No. 1. (Blood solution.)

Date.	Age. Days.	Total Ammonia.		Bacteria per cc.
		Filtered.	Unfiltered.	
March 3	..	....	....	262 (3 molds)
March 4	1	....	....	800
March 15	12	....	....	1,260,000
March 25	22	{ .300 { .348	{ .700 { .670	

15. 2 liters of same solution as 13, but with the addition of 50 cc. of No. 2. (Glycerine and milk solution.)

Date.	Age. Days.	Total Ammonia.		Bacteria per cc.
		Filtered.	Unfiltered.	
1892.				
March 3	..	....	....	147 (34 molds)
March 4	1	....	....	2,800
March 15	12	....	....	1,300,000
March 25	22	{.150 .188	{.650 .788	

16. 2 liters of same solution, but with the addition of 50 cc. of No. 3. (Milk solution.)

Date.	Age. Days.	Total Ammonia.		Bacteria per cc.
		Filtered.	Unfiltered.	
March 3	..	....	....	291 (3 molds)
March 4	1	....	....	1,400
March 15	12	....	....	1,108,000
March 25	22	{.140 .140	{.550 .572	

A few of the conditions affecting the disappearance of this nitrogen as a result of the decomposition of the nitrates have been investigated. The experiments on this line did not, however, throw any light on what becomes of the element. Is it that this nitrogen does not take any part in the life history of the plant forms, and therefore has it no influence on the final result as we interpret it? Is it rejected by all the busy organisms which successively play their parts in this well-marked life-cycle? Is it stored away in some form which has escaped the scrutiny of the chemist, or has it passed off in some gaseous excretion?

These questions led to further experiments, with two objects in view: (*a*) To make this nitrogen appear as albuminoid ammonia in the solution; (*b*) to find if this nitrogen existed as a gaseous product, excreted by the organisms or rejected by them. The first series of investigations is as yet far from complete.

The only successful experiment in this line was made by adding two cubic centimeters of glycerine per liter of the usual milk and

nitrate solution. The results indicate that a part of the nitrogen was fixed. The nitrate and nitrite figures are in general like those of similar solutions without the glycerine. The solution, however, as far as its external behavior was noted, acted in a radically different manner. Large quantities of gas, apparently carbon dioxide, were given off. This active fermentation began about the eleventh day and continued for over a month, the solution being quite sour, with an odor of yeast. The organisms which developed in this solution in great abundance are a bright red, and have retained their color for five years.

2. { Glycerine, 16 cc.
Milk, 8 cc.
KNO_3. (N = 4.00 parts per 100,000.)
City Water, 8 liters.

Date.	Age. Days.	Ammonia.			Nitrogen as Nitrites.	Nitrogen as Nitrates.
		Free.	Albuminoid.	Total.		
1891.						
May 4	..	.052	.011	.695	000	4.100
May 4, 4 P.M.	..	....	....	....	.0003	.....
May 6	2	.108	....	....	.400	.....
May 7	3	....	....	....	1.080	.800
May 8	4	....	....	....	2.650	.....
May 9	5	....	....	....	1.750	.....
May 20	16	....	....	....	000	.020
May 29	25	....	....	....	.0005	.002
June 14	31	....	....	....	.0003	.003
June 21	48	.007	....	1.665	.0001	000

No green growth has appeared in this solution.

In the investigation of the gaseous products of the decomposition much more work has been done.

On March 13, 1894, three milk solutions were made up with potassium nitrate after the usual manner. Two of these were so arranged that the gas evolved could be collected over mercury, any air other than that dissolved in the water of each bottle being carefully excluded. The composition of the gases dissolved in the water of

each bottle was determined by their removal from a standard volume by means of a Sprengel pump and their examination in a Frankland gas apparatus. The gases evolved were also determined[1] and finally those dissolved in the resulting sewage. A few chemical tests were made of the contents of the third bottle during the decomposition. The same work was repeated in June, 1895, the apparatus being so modified that chemical tests might be made of the solutions at the same time that the gaseous products were being investigated. The results as arranged are self-explanatory, and show at once what has become of the nitrogen of the nitrate.[2] Two of the investigations show that within less than 3 per cent. this nitrogen can be accounted for. The third shows that 7 per cent. more nitrogen is evolved than can be accounted for by the decomposition of the nitrate, a discrepancy we cannot explain. However, it is clearly demonstrated that practically all the nitrogen of the nitrate is freed as the elementary gas.

The rapid decrease in "oxygen consumed"[3] is also shown to be the result of the early escape of carbon as the dioxide, and makes it clear that this test is useless as a measure of pollution, however valuable it may be as an aid in ascertaining the nature of the organic matter present.

18. *Experimental Data.*[4]

Potassium Nitrate: .3125 gram per 1,000 cc. of City Water.
(Nitrogen = 4.33 parts per 100,000.)
Milk: 1 cc. per 1,000 cc. of City Water.
Three bottles were filled:

A, 8,580 cc.
B, 8,660 cc.
C, 8,380 cc.

To each bottle had been previously added 10 cc. of an old milk solution (3).

Chemical tests were made on Bottle C. Gas evolved by A and B was collected over mercury.

Started March 9, 1894, 2.15 P.M. Putrefaction was very rapid. All gas was evolved by March 17.

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[1] By Hempel's Method.

[2] It has already been shown by previous investigators that nitrogen gas is sometimes a product of decomposition. (See recent article by George W. Fuller in Twenty-Sixth Annual Report of State Board of Health of Massachusetts, pp. 472, 522, 581.)

[3] See Table, p. 51.

[4] We are indebted to Professor A. H. Gill for valuable advice, as well as the facilities for carrying on this work.

Bottle C.

Date.	Age. Days.	Nitrogen as Nitrites.	Nitrogen as Nitrates.
1894.			
March 9, 2.15 P.M.	..	.....	4.33
March 10, 10 A.M.	1	.....	2.80
March 12	3	.....	0.25
March 13	4	1.500	....
March 15	6	.....	000
March 17	8	000	....
March 21	12	Signs of green growth at bottom of bottle.	

Gases Dissolved in City Tap Water used in making up Solutions ($t = 11°$ C.).

	Bottle A.	Bottle B.	Per cent. by Volume.
Nitrogen (by difference)	201.80 cc.[1]	203.70 cc.	73.21
Oxygen	72.91	73.58	26.43
Carbon Dioxide	1.00	1.01	.36

Gases Evolved in First Four Days of Putrefaction.

	Bottle A.		Bottle B.	
	Volume.	Per cent.	Volume.	Per cent.
Nitrogen	76.91 cc.	93.75	52.49 cc.	96.37
Oxygen	.37	.45	000	.....
Carbon Dioxide	2.10	2.56	1.99	3.63
Methane	2.66	3.24	000	.....
Nitrous Oxide	....	....	000	.....

No more gas was collected from Bottle A, owing to breakage of connection.

[1] All gas volumes are calculated at standard temperature and pressure.

Gases Evolved March 14–17. Bottle B.

	First Portion.		Second Portion.		Total.
	Volume.	Per cent.	Volume.	Per cent.	
Nitrogen	80.87 cc.	97.58	149.56 cc.	97.81	282.92 cc.
Carbon Dioxide	1.31	1.54	2.23	1.46	4.54
Methane	.73	.88	1.11	.73	1.84

18. *Experimental Data* (concluded). Gas Dissolved in Resulting Sewage.

	Volume.	Per cent.
Nitrogen	212.80 cc.	71.24
Carbon Dioxide	76.58	25.64
Oxygen	9.34	3.12

Total Nitrogen Gas Produced in Milk Solution. — 292.02 cc. = 4.23 parts per 100,000, or 97.57 per cent. possible nitrogen from dissolved nitrate.

19. *Experimental Data.* Solution prepared and inoculated exactly like Solution 18. Two bottles filled:

A, 8,600 cc.
B, 9,010 cc.

Solution prepared June 19, 1895, 4.30 P.M. Bottle A.

Date.	Age. Days.	Total Ammonia.	Nitrogen as Nitrates.	Remarks.
1895.				
June 19	..	.803	4.33	Putrefaction proceeding very slowly.
June 21	2	....	.70	
July 2	13	.864	000	No signs of green growth.
		Bottle B.		
1895.				
June 19	..	.830	4.33	
June 21	2	....	.50	
July 2	13	....	000	No signs of green growth.

Practically no gas was evolved from either bottle until after the third day. The gas evolution from both bottles was much slower than in the experiment of the previous year, Bottle B producing notably more gas than Bottle A.

19. *Experimental Data* (concluded). Gases Dissolved in City Tap Water used in making up Solutions (t = 22.5° C.).

	Bottle A.	Bottle B.	Per cent. by Volume.
Nitrogen	122.7 cc.	128.5 cc.	69.86
Oxygen	44.87	46.99	25.57
Carbon Dioxide	8.05	8.44	4.57

Gases Evolved in Putrefaction.

	Bottle A.	Per cent. by Volume.	Bottle B.	Per cent. by Volume.
Nitrogen	195.80 cc.	98.42	235.20 cc.	98.85
Carbon Dioxide	3.14	1.58	2.73	1.15
Carbon Monoxide	000	....	000	....
Methane	000	....	000	....
Oxygen	000	....	000	...

Gases Dissolved in Resulting Sewage.

Nitrogen	217.40 cc.	77.80	227.50 cc.	75.54
Carbon Dioxide	58.03	20.75	68.73	22.82
Oxygen	4.09	1.45	4.95	1.64

Total Nitrogen Gas Produced in Sewage of Bottle A. — 290.5 cc. = 4.24 parts per 100,000, or 97.92 per cent. possible nitrogen from dissolved nitrate.

Total Nitrogen Gas Produced in Sewage of Bottle B. — 334.2 cc. = 4.66 parts per 100,000, or 107.6 per cent. of the nitrogen gas possible from nitrate dissolved.

It is somewhat hazardous to theorize as yet on the chemistry of these changes, especially with our limited knowledge of the nature of the powerful life agencies at work in nature's laboratory through the

medium of bacteria. A natural inference would be that ammonium nitrate is formed, which breaks up into water and nitrogen gas. On the line of this theory the thought at once occurs, can we not introduce some substance in itself not readily decomposed by the processes of fermentation which, through the subtle reaction of bacterial life, might be made to form substituted ammonia products or their analogues which, breaking up into stable compounds, would result in fixing the nitrogen?

The addition of glycerine to the milk solutions was suggested to us. The results in this case certainly point to the fixing of some of the nitrogen, but further investigations, which we have in hand, are necessary to prove this beyond all doubt.

The conclusion may be stated thus: Whenever nitrates are added to decomposable organic matter not sterile, under such conditions that the growth of the bacteria requires more oxygen than the solution affords, the plants will take it from the nitrates, setting free nitrites, which in time are decomposed, setting free nitrogen.

Therefore, a very nice balance exists between the organic matter to be decomposed, the oxygen at hand, and the plants to do the work.

A clear understanding of these relations is of great importance to the agriculturist and especially to the sewage farmer, since it is easy to lose all the nitrogen once gained by an imprudent addition of food. In fact, to save nitrates already in the soil the sewage must be so applied that the conditions are to the highest degree favorable for contact with the air, as, for instance, in very thin layers. Aëration by the passage of air through the sewage in bulk is quite useless, however thorough the process. Again, even under the most favorable conditions it will be seen that the success of nitrogen storage is exceedingly dubious. The inference is that the most feasible way of economizing nitrogen is to feed it to the growing green plant[1] only as fast as it can be assimilated, rather than to attempt to prepare the soil in advance and risk having the element thrown back in its primal state into the atmosphere by the excretory processes of hordes of oxygen-loving bacteria. Even in spite of aëration certain fermentative organisms seem to prefer to take their supply of oxygen from

[1] George W. Fuller, Twenty-Sixth Annual Report of the State Board of Health of Massachusetts, p. 493.

its nitrogen combinations. Hence loss of nitrogen is liable to occur, if it is not inevitable, when a solution containing certain kinds of decomposing organic matter is added to a soil or water already nitrified.

In this connection the recent paper by George W. Fuller in the *Twenty-Sixth Annual Report of the State Board of Health of Massachusetts*, with its rich store of valuable analytical data, is most suggestive. We have already referred in footnotes to the conclusion of the author concerning the effect of aëration, the loss of nitrogen, and the influence of green growth on this loss as corroborative of our own. Can we not, on the other hand, point to the results of our investigations as shedding light on several points touched on in this work? For instance, is not the greater efficiency of coarse material over fine in sewage purification accounted for by the fact that less nitrogenous matter is retained to stimulate growth of reducing bacteria as well as by the explanation of more efficient air supply (p. 515)?

Again, cannot some of the irregularities of the working of water filters (p. 637) and the variation in nitrates in the Merrimac River water (p. 651) also be made clear if we consider that, during the time in which the nitrates were diminished, the food supply (sewage) was increased, resulting in the decomposition of the nitrates previously existing?

Certainly the fixing of nitrogen in a water or soil in a form available for higher vegetation is a problem requiring further consideration. In a subsequent paper we shall consider some of these points in question.

THE GRADUATION OF A 100-INCH PHOTOMETER BAR.

By W. LINCOLN SMITH, S.B.

Received February 15, 1896.

HAVING had occasion some time since to lay out two new photometer bars for use in the Electrical Engineering Laboratory of the Institute, I was desirous of finding a table of scale readings in inches and corresponding ratios of unknown to standard which, when multiplied by the value of the standard in candle powers, should give directly the value of the unknown.

As I failed to find such a table at hand, it was necessary to compile one, which I have appended here, together with the method of obtaining it.

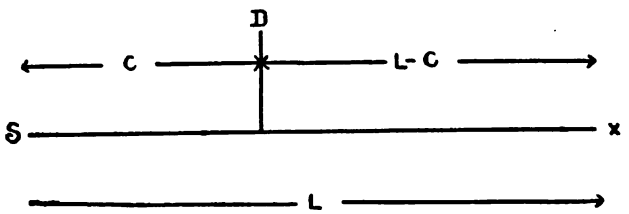

Fig. I

In the figure let L be the length of the bar, S the standard light, X the unknown light, D the disc, c the distance from S to D, and $L - c$ the distance from D to X. Then

$$X : S = (L - c)^2 : c^2;$$

or as

$$\frac{X}{S} = R,$$

we have

$$Rc^2 = (L - c)^2.$$

This gives us $$c = \frac{L}{\sqrt{R} + 1},$$

or for a 100-inch bar $$c = \frac{100}{\sqrt{R} + 1},$$

and for any given value of R will give us the corresponding scale reading in inches.

As the direct calculation of about 500 points would take a considerable time, I began to plot a set of curves, but after a short time noticed that the points could be directly obtained without calculation in the following manner.

Let us take a set of tables (Barlow's original set, or a reprint, is best, as, for direct work to four places of significant figures, the table should run up to 10,000) and work as follows:

Enter the table with the ratio, find its square root, add 1, and the result is composed of the significant figures of the reciprocal of the corresponding scale reading in inches.

Thus for example:

$$R = 20. \quad \sqrt{R} = 4.4721. \quad \sqrt{R} + 1 = 5.4721.$$

Entering the table now with this number as a reciprocal, we shall find:

No.	Rec.
1827	.00054734
1828	.00054705,

from which we can easily see that 1828 is the desired number, and the position of the decimal point is 18.28.

Again: $R = 8.10$, $\sqrt{R} = 2.84605$ (we find this square root opposite 810 in the table), $\sqrt{R} + 1 = 3.84605$, and the nearest corresponding number is 26.00, the reciprocal of which is .0384615.

If we wish a 200-inch bar, we must mark off 36.56, 52.00, etc., instead of 18.28, 26.00, etc.

The following table then gives the ratios and scale readings that are desirable on a bar for use in photometric work on incandescent and arc lamps.

Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.
.10	75.97	.41	60.97	.72	54.10	1.03	49.63	1.34	46.35
.11	75.09	.42	60.68	.73	53.93	1.04	49.51	1.35	46.26
.12	74.27	.43	60.39	.74	53.76	1.05	49.39	1.36	46.16
.13	73.50	.44	60.12	.75	53.59	1.06	49.27	1.37	46.07
.14	72.77	.45	59.85	.76	53.42	1.07	49.15	1.38	45.98
.15	72.08	.46	59.58	.77	53.26	1.08	49.04	1.39	45.89
.16	71.43	.47	59.33	.78	53.10	1.09	48.93	1.40	45.80
.17	70.81	.48	59.07	.79	52.94	1.10	48.81	1.41	45.72
.18	70.21	.49	58.82	.80	52.78	1.11	48.70	1.42	45.63
.19	69.64	.50	58.57	.81	52 63	1.12	48.59	1.43	45.54
.20	69.10	.51	58.34	.82	52.48	1.13	48.48	1.44	45.45
.21	68.58	.52	58.10	.83	52.33	1.14	48.36	1.45	45.37
.22	68.07	.53	57.87	.84	52.18	1.15	48.25	1.46	45.28
.23	67.58	.54	57.64	.85	52.03	1.16	48.14	1.47	45.20
.24	67.12	.55	57.42	.86	51.88	1.17	48.04	1.48	45.12
.25	66.66	.56	57.20	.87	51.74	1.18	47.93	1.49	45.03
.26	66.23	.57	56.98	.88	51.60	1.19	47.83	1.50	44.95
.27	65.81	.58	56.77	.89	51.46	1.20	47.72	1.51	44.87
.28	65.40	.59	56.56	.90	51.32	1.21	47.62	1.52	44.79
.29	65.00	.60	56.35	.91	51.18	1.22	47.51	1.53	44.71
.30	64.61	.61	56.15	.92	51.04	1.23	47.41	1.54	44.62
.31	64.24	.62	55.95	.93	50.90	1.24	47.31	1.55	44.54
.32	63.87	.63	55.75	.94	50.77	1.25	47.21	1.56	44.47
.33	63.51	.64	55.55	.95	50.64	1.26	47.11	1.57	44.39
.34	63.17	.65	55.36	.96	50.51	1.27	47.01	1.58	44.31
.35	62.83	.66	55.17	.97	50.38	1.28	46.92	1.59	44.23
.36	62.50	.67	54.98	.98	50.25	1.29	46.82	1.60	44.15
.37	62.18	.68	54.80	.99	50.12	1.30	46.72	1.61	44.08
.38	61.86	.69	54.62	1.00	50.00	1.31	46.63	1.62	44.00
.39	61.55	.70	54.44	1.01	49.88	1.32	46.54	1.63	43.92
.40	61.25	.71	54.27	1.02	49.76	1.33	46.44	1.64	43.85

Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.
1.65	43.77	1.96	41.67	2.54	38.55	3.16	36.01	4.20	32.79
1.66	43.70	1.97	41.61	2.56	38.46	3.18	35.93	4.25	32.66
1.67	43.62	1.98	41.55	2.58	38.37	3.20	35.86	4.30	32.54
1.68	43.55	1.99	41.48	2.60	38.28	3.22	35.79	4.35	32.41
1.69	43.48	2.00	41.42	2.62	38.19	3 24	35.72	4.40	32 28
1.70	43.41	2.02	41.30	2.64	38.10	3.26	35.64	4.45	32.16
1.71	43.33	2.04	41.18	2.66	38.01	3.28	35.57	4.50	32.04
1.72	43.26	2.06	41.06	2.68	37.92	3.30	35.50	4.55	31.92
1.73	43.19	2.08	40.95	2.70	37.83	3.32	35.44	4.60	31.80
1.74	43.12	2.10	40.83	2.72	37.75	3.34	35.37	4.65	31 68
1.75	43.05	2.12	40.72	2.74	37.66	3.36	35.30	4.70	31.57
1.76	42.98	2.14	40.60	2.76	37.58	3.38	35.23	4.75	31.45
1.77	42.91	2.16	40.49	2.78	37.49	3.40	35.16	4.80	31.34
1.78	42.84	2.18	40.38	2.80	37.41	3.42	35.10	4.85	31.22
1.79	42.77	2.20	40.27	2.82	37.32	3.44	35.03	4.90	31.12
1.80	42.70	2.22	40.16	2.84	37.24	3.46	34.97	4.95	31.01
1.81	42.64	2.24	40.05	2 86	37.16	3.48	34.90	5.00	30.90
1.82	42.57	2.26	39.95	2.88	37.08	3.50	34 83	5.05	30.79
1.83	42.50	2.28	39.84	2.90	37.00	3.55	34.67	5.10	30 69
1.84	42.44	2.30	39.74	2.92	36.92	3.60	34.51	5.15	30.59
1.85	42.37	2.32	39.63	2.94	36.84	3.65	34.36	5.20	30.49
1.86	42.30	2.34	39.53	2.96	36.76	3.70	34.21	5.25	30 38
1.87	42.24	2.36	39.43	2.98	36.68	3.75	34.05	5.30	30.28
1.88	42.18	2.38	39.33	3.00	36.60	3.80	33.90	5.35	30.18
1.89	42.11	2.40	39.23	3.02	36.53	3.85	33.76	5.40	30.09
1.90	42.04	2.42	39.13	3.04	36.45	3.90	33.62	5.45	29.99
1.91	41.98	2.44	39.03	3.06	36.37	3.95	33.47	5.50	29.89
1.92	41.92	2.46	38.93	3.08	36.30	4.00	33.33	5.55	29.80
1.93	41.85	2.48	38.84	3.10	36.23	4.05	33.19	5.60	29.70
1.94	41.79	2.50	38.75	3.12	36.15	4.10	33.06	5.65	29.61
1.95	41.73	2.52	38.65	3.14	36.08	4.15	32.92	5.70	29.52

Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.
5.75	29.43	7.25	27.08	8.75	25.27	11.25	22.97	18.75	18.76
5.80	29.34	7.30	27.01	8.80	25.21	11.50	22.77	19.00	18.66
5.85	29.25	7.35	26.95	8.85	25.16	11.75	22.57	19.25	18.56
5.90	29.16	7.40	26.88	8.90	25 10	12.00	22.40	19.50	18.46
5.95	29.07	7.45	26.81	8.95	25.05	12.25	22.23	19.75	18.37
6.00	28.99	7.50	26.75	9.00	25.00	12.50	22.05	20.00	18.28
6.05	28.90	7.55	26.69	9.05	24.95	12.75	21.88	20.50	18.09
6.10	28.82	7.60	26.62	9.10	24.90	13.00	21.71	21.00	17.91
6.15	28.74	7.65	26.55	9.15	24.85	13.25	21.55	21.50	17.74
6.20	28.66	7.70	26.49	9.20	24.79	13.50	21.39	22.00	17.57
6.25	28.58	7.75	26.43	9.25	24.74	13.75	21.24	22.50	17.41
6.30	28.49	7.80	26.37	9.30	24.69	14.00	21.09	23.00	17.25
6.35	28.41	7.85	26.30	9.35	24.64	14.25	20.94	23.50	17.10
6.40	28.33	7.90	26.24	9.40	24.60	14.50	20.80	24 00	16.95
6.45	28.25	7.95	26.18	9.45	24.55	14.75	20.66	24.50	16.81
6.50	28.17	8.00	26.12	9.50	24.50	15.00	20.52	25.00	16.67
6.55	28.09	8.05	26.06	9.55	24.45	15.25	20 39	25.50	16.53
6.60	28.01	8.10	26.00	9.60	24.40	15.50	20.26	26.00	16.40
6.65	27.94	8.15	25.94	9.65	24.35	15.75	20.13	26.50	16.27
6.70	27.87	8.20	25.88	9.70	24.30	16.00	20.00	27.00	16.14
6.75	27.79	8.25	25.82	9.75	24.26	16.25	19.88	27.50	16.01
6.80	27.72	8.30	25.77	9.80	24.21	16.50	19.75	28.00	15.89
6.85	27.64	8.35	25.71	9.85	24.17	16.75	19 63	28.50	15.78
6.90	27.57	8.40	25.65	9.90	24.12	17.00	19.51	29.00	15.66
6.95	27.50	8.45	25.60	9.95	24.07	17.25	19.39	29.50	15.55
7.00	27.43	8.50	25.54	10.00	24.03	17.50	19.28	30.00	15.45
7.05	27.36	8.55	25.48	10.25	23.80	17.75	19.18		
7.10	27.29	8.60	25.43	10.50	23.58	18 00	19.07		
7.15	27.22	8.65	25.37	10.75	23.37	18.25	18.97		
7.20	27.15	8.70	25.32	11.00	23.17	18.50	18.86		

Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.	Ratio.	Scale.
31	15.23	43	13.23	60	11.43	90	9.54	150	7.55
32	15.02	44	13.10	62	11.27	95	9.31	155	7.44
33	14.83	45	12.97	64	11.11	100	9.09	160	7.33
34	14.64	46	12.85	66	10.96	105	8.89	165	7.22
35	14.46	47	12.73	68	10.82	110	8.70	170	7.12
36	14.28	48	12.61	70	10.67	115	8.53	175	7.03
37	14.12	49	12.50	72	10.54	120	8.36	180	6.94
38	13.96	50	12.39	74	10.41	125	8.21	185	6.85
39	13.80	52	12.18	76	10.29	130	8.06	190	6.77
40	13.65	54	11.98	78	10.17	135	7.92	195	6.68
41	13.51	56	11.79	80	10.06	140	7.79	200	6.60
42	13.37	58	11.61	85	9.79	145	7.67		

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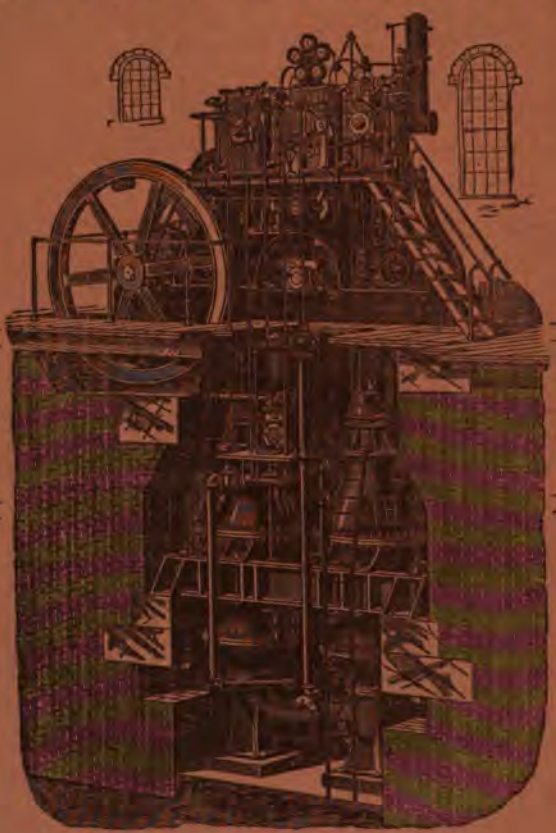

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Vol. IX. JUNE-SEPTEMBER, 1896. Nos. 2 and 3.

DOUBLE NUMBER.

TECHNOLOGY QUARTERLY

AND PROCEEDINGS OF THE

SOCIETY OF ARTS

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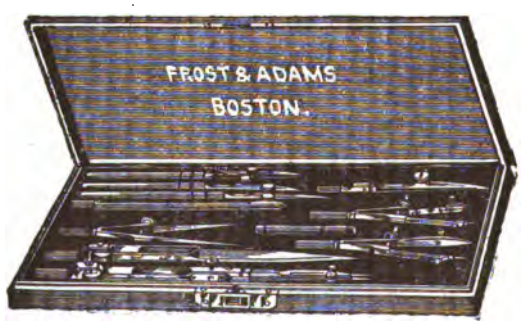

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TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. IX. JUNE AND SEPTEMBER, 1896. No. 2–3.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-FOURTH YEAR, 1895–96.

THURSDAY, April 9, 1896.

THE 485th meeting of the SOCIETY OF ARTS was held at the Institute on this day at 8 P.M., Professor H. P. Talbot in the chair.

The record of the last meeting was read and approved. The Secretary reported that the Executive Committee had approved the following nominations for associate membership: Macy S. Pope, of Boston; Edward D. Brown, of New York; Howard C. Forbes, of Boston; Parker C. Newbegin, of Houlton, Maine; Albert H. Sawyer, of Boston; George W. Sherman, of Cambridge; George R. Underwood, of Peabody; Hans Birkholz, of Milwaukee, Wisconsin; Edward P. Boone, Jr., of Boston; and John F. Low, of Chelsea. These nominees were duly elected. The Secretary announced the receipt of invitations to the exhibition of the Camera Club.

The President then introduced Mr. Arthur D. Little, of Boston, who read a paper on "Paper and Paper Testing." The various classifications of paper by composition and by physical properties were given. Precautions required in testing were discussed, and then the various methods of testing paper were described, and many of them

were illustrated by experiments. At the close of his remarks Mr. Little exhibited a remarkable collection of very rare and beautiful Russian water markings.

A discussion followed, and then, after the speaker had been thanked for his very interesting paper, the Society adjourned.

THURSDAY, April 23, 1896.

The 486th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Professor Allen in the chair.

The record of the last meeting was read and approved. On motion, it was voted to authorize the President to appoint a committee to nominate candidates for election to the Executive Committee for the next year.

Major W. R. Livermore, of the United States Engineers, was then introduced and read a paper on the "Arts and Sciences in the Twentieth Century." The immense accumulation of knowledge at the present time was dwelt upon, and it was pointed out that there is need of coöperation between the different branches of science. For this a common language is necessary, and the graphic methods of presenting facts were shown to be capable of wide application in this connection. A number of charts and tables were exhibited by means of the lantern to illustrate points made in the paper.

A discussion followed, after which the speaker was thanked by the chair for his very interesting and suggestive paper, and the Society adjourned.

THURSDAY, May 14, 1896.

The 34th annual meeting (487th meeting) was held at the Institute on this day at 8 P.M., the President in the chair and a quorum of members present.

The record of the previous meeting was read and approved.

Mr. Lowe presented the report of the Nominating Committee, recommending for the Executive Committee for the next year Messrs. George W. Blodgett, Percival Lowell, Henry M. Howe, Walter S. Allen, and Desmond FitzGerald.

Mr. Woodbury, of the Executive Committee, reported that the committee nominated Dr. R. P. Bigelow for Secretary for the ensuing year.

The reports were accepted, the Society proceeded to ballot, and these gentlemen were declared duly elected.

Mr. Woodbury read the report of the Executive Committee as follows in part:

The Executive Committee of the SOCIETY OF ARTS presents as its annual report for the 34th year the following:

MEMBERSHIP.

Life members May, 1895		71
Became life members by operation of the By-Laws		2
		73
Died during the year		6
Life members at the present time		67
Number of associate members May, 1895		181
Number of associate members elected during the year		118
		299
Died	2	
Resigned	5	
Dropped for non-payment of dues	1	
Transferred to life membership	2	
		10
Present number of associate members		289

MEETINGS.

Including the present meeting, thirteen have been held during the year, at which fourteen papers will have been read. As all of these (with three exceptions) have been, or will shortly be, published in the TECHNOLOGY QUARTERLY it is not thought necessary to recapitulate them here. Thirteen papers published in the QUARTERLY have been read by title.

Three addresses illustrating original work of the speakers are especially worthy of mention, viz.: The paper read January 9 on "A New Method of Studying the Light of Alternating Arc Lamps," by Professor W. L. Puffer, of the Institute; the exhibition given by Mr. Louis Derr, of the Institute, February 13, of "Apparatus for Showing the Phase Relations of Alternating Currents;" and the demonstration given by Professor Cross on the same evening of Professor Röntgen's X-Rays.

The Executive Committee would be much gratified if members having important information of a scientific or practical character would communicate with the Secretary with a view to its being brought before the Society; also if they would make more widely known among their friends the scope and purpose of the Society, and thus add to the attendance and to the interest of the meetings.

(Signed) FRANCIS A. WALKER,
GEORGE W. BLODGETT,
HENRY M. HOWE,
C. J. H. WOODBURY,
ROBERT P. BIGELOW,
Of the Executive Committee.

The report was accepted and ordered placed on file. The Secretary read the report of the Meteorological Committee as follows:

The undersigned members of the Meteorological Committee beg leave to report that they have watched with interest the development of the work of the Boston Station of the Weather Bureau, which is still in charge of Mr. J. W. Smith. The improved method of printing the Daily Weather Maps, proposed by Mr. Smith and mentioned in last year's report, has been put in practice, and Mr. Smith will introduce the process in other cities by order of the chief of the bureau. Briefly described, the isobars and isotherms with the necessary explanatory figures are engraved at the station on a metal plate representing the base maps of the United States. From a stereotype of this the maps are printed, together with tabular matter and predictions set in type. Large editions of the maps are printed more quickly than were the former cyclostyle copies, and although the present map is smaller in size, it is more legible.

Another innovation during the year has been the introduction of special hurricane signals. For night signals more powerful electric lights than heretofore are now displayed and at a greater height above the post office tower, thereby rendering them less likely to be mistaken by mariners for other lights.

The committee have to announce that the Monthly Bulletin of the New England Weather Service has given place to a similar Climate and Crop Report, which it is the intention of the chief to issue in place of the existing State Weather Service Bulletins. A uniform method of publishing meteorological data throughout the United States is highly desirable, and it is a compliment to J. Warren Smith that the observations under his direction in New England should be the first to be published in the new form.

(Signed) WILLIAM H. NILES, A. LAWRENCE ROTCH, } *Meteorological Committee.*

The report was accepted and ordered placed on file.

The following gentlemen were elected associate members: George Wyman Hamilton, of Boston; Fred F. Moore, of South Framingham; G. W. Patterson, Jr., of Ann Arbor, Michigan; Walter W. Reed, of Waltham; and A. Forrest Shattuck, of Syracuse, New York.

The following papers (published in the present number of the QUARTERLY) were presented by title: "Englacial Drift," by W. O. Crosby; "Notes on the Best Form of Cross Section for the Coils of a Galvanometer," Part I, by F. A. Laws; and "Some Experiments on the Growth of Diatoms," by G. C. Whipple.

The President then introduced Mr. Horace See, of New York, who read a paper on the "Recent Development of Large Freight Steamers." The paper was illustrated by means of views and plans thrown upon the screen by the lantern. First, the development of

freight steamers from their beginning to the present was sketched; then the recent improvements in large freight steamers were described, especially the important improvements in the machinery, resulting in greater economy of space and of fuel.

At the close of the paper the President thanked the speaker, and the Society adjourned.

ROBERT PAYNE BIGELOW, *Secretary.*

DESCRIPTION AND COMPUTATION OF A TWENTY-FOUR HOUR DUTY TEST ON THE TWENTY MILLION GALLON LEAVITT PUMPING ENGINE AT CHESTNUT HILL.

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

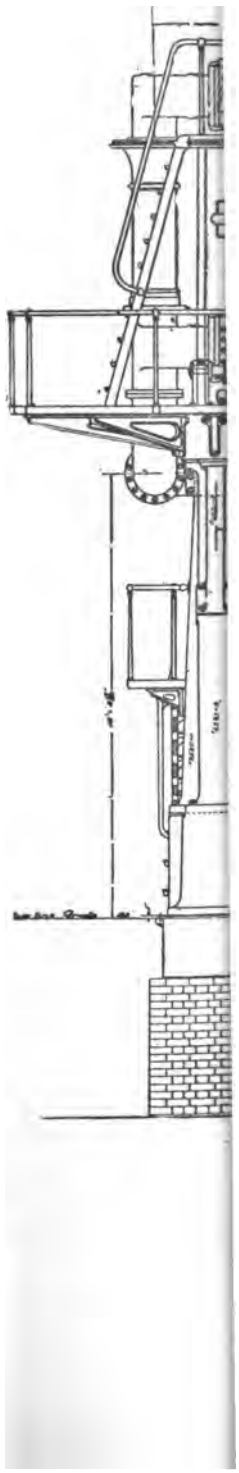
IV.

BY EDWARD F. MILLER, S.B.

Read March 12, 1896.

THE test which I am about to speak of was made on May 1st and 2d of last year by about ninety students of the senior class of the Massachusetts Institute of Technology. The test formed a part of the regular work of the Engineering Laboratories, and was made under the direction of the laboratory instructing staff. The following brief description of the engine and boiler is taken from the 1894 report of the City Engineer, Mr. William Jackson.

The engine (Plate 1) was built by the Quintard Iron Works of New York, from designs furnished by E. D. Leavitt, of Cambridge. It is a triple expansion, three-crank rocker engine, with pistons 13.7, 24.375, and 39 inches in diameter and 6 foot stroke. The cylinders are vertical and inverted, and are carried, together with valve gear, on an entablature supported by six vertical and six diagonal columns. The steam and exhaust valves are gridiron slides worked by cams on a horizontal shaft, which is driven by gearing from the crank shaft. The cut-off of the high pressure cylinder is regulated by the governor through the agency of a hydraulic cylinder, which advances or retards the cut-off cam by means of a spiral sleeve; the cut-offs of the other engines are fixed. The steam passes into the high pressure cylinder through a separator forming a part of the inlet side pipe. After expanding in this cylinder it passes through a tubular reheater to the intermediate cylinder, and thence through another similar reheater to the low pressure cylinder. The reheaters have steam of boiler pressure, or about 185 pounds per square inch on the inside of the tubes, and the working steam on the outside. All the cylinders are steam-jacketed on



the head and barrels, the low pressure cylinder with steam at 100 pounds and the others at 185 pounds. The jackets and reheaters using steam of boiler pressure are drained back to the boiler, while the low pressure cylinder jackets and the working steam side of the reheaters are drained by means of automatic traps discharging into the hot well.

The engine crossheads work on guides cast in the vertical columns. The motion is transmitted from the crossheads by links to beams or rockers carried in pedestals on the bedplate of the engine. From these beams the connecting-rods work off in one direction and the pump links in the opposite direction, but inclined at an angle of about 30 degrees from the horizontal. The leverage of the various pins in the beams is such that the stroke, which is 6 feet in the case of the steam pistons, is reduced to 4 feet for the pump plungers, which is also the amount of the double throw of the cranks. The crank shaft has three cranks set at angles of 120 degrees, the low pressure crank leading, followed by the intermediate and high pressure cranks. The shaft is carried in four adjustable four-box pedestals, with overhung end cranks. Between two of these pedestals is the fly-wheel, and between the other two the gear for driving the cam shaft.

There are three double-acting inclined pumps (Plate 2), having plungers 17.5 inches in diameter and 4 feet stroke. The pumps are seated on foundations at a lower level than those for the engines, the pump chambers being tied to the engine bedplates by horizontal girders, as well as by the pump crosshead guides, which are inclined 30 degrees from the horizontal. This peculiar arrangement of inclined pumps was found necessary to suit existing conditions of engine house, pump well, etc. The pump bases or suction chambers, six in number, one for each end of each pump, are connected together, and the bases of each pump are connected by a separate suction pipe. The lower or working pump chambers are surrounded by annular spaces throughout their height, forming vacuum chambers. The upper pump chambers contain the delivery nozzles, and above these are the air chambers, all six of the latter being connected by pipes.

Each end of each pump has one suction and one delivery valve, consisting of a number of rigidly connected rings covering annular openings in the valve seats. The speed necessary for the required capacity of 20,000,000 gallons in twenty-four hours is fifty revolu-

tions per minute, but the engine has been designed to run easily at sixty revolutions per minute. The head pumped against is 128 feet, or about 55 pounds per square inch.

Each pump contains one suction and one delivery valve, each about 3 feet in diameter. The use of these large valves, together with the phenomenally high speed, is made possible by the method of working the pump valves, which is the invention of Professor Riedler, of the Royal Polytechnic School, of Berlin, Germany. This invention consists in closing each valve positively at just the moment of reversal of stroke by means of levers and rods. After closing the valves the mechanism moves out of the way, leaving the valves free to open automatically.

Although the design for the Chestnut Hill engine was begun first, the large pumping engine of the Bethlehem Iron Company, also of Mr. Leavitt's design, was the first Riedler engine in operation in this country, having been started more than a year before the Boston engine. There are now quite a number of Riedler engines in this country, some running as fast as 120 revolutions per minute.

The condenser of the Chestnut Hill engine is of the surface type, having 1,410 square feet of tube surface, with water passing through the tubes. The condensing water is taken from one of the upper pump chambers, and after passing through the condenser is delivered into the force main. A butterfly valve in one of the pump discharge pipes permits the quantity of condensing water to be easily regulated. The air pump is of the single-acting bucket type, 24″ diameter and 12-inch stroke, situated directly below the condenser, and worked by an arm on one of the pump valve gear rocker shafts.

Steam for the engine is furnished by a Belpaire fire-box boiler (Plate 3) having two separate furnaces and a common combustion chamber. The boiler is 34 feet 4 inches long, with a least internal diameter of shell of 90 inches. The tubes are 201 in number, 3 inches in diameter, and 16 feet long. The feed water, before entering the boiler, passes through a Green economizer, where it is heated by the escaping gases.

Arrangements and Changes Made for the Test.

The air pump ordinarily delivered into a closed hot well, into which the drips from the separator and from the working sides of the first and second receivers were discharged. The steam used by the feed

TE 2.

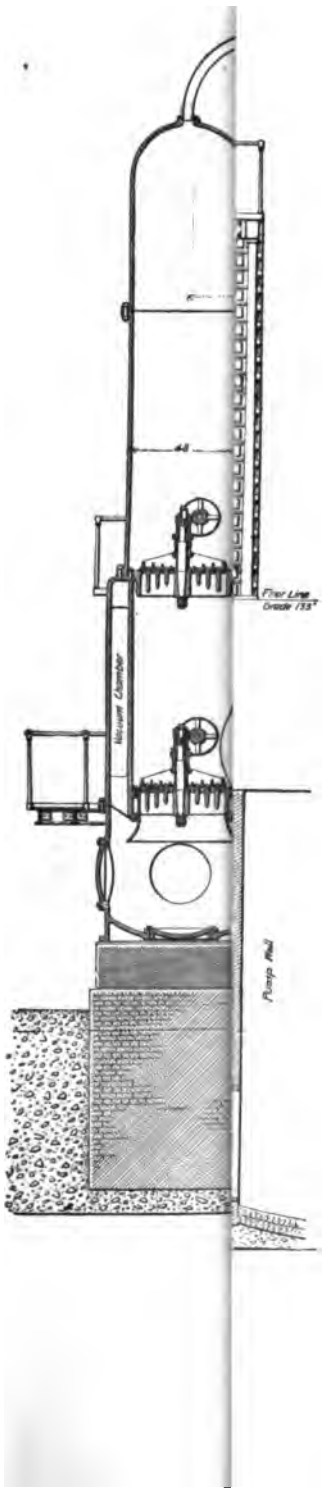


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PLATE 3.

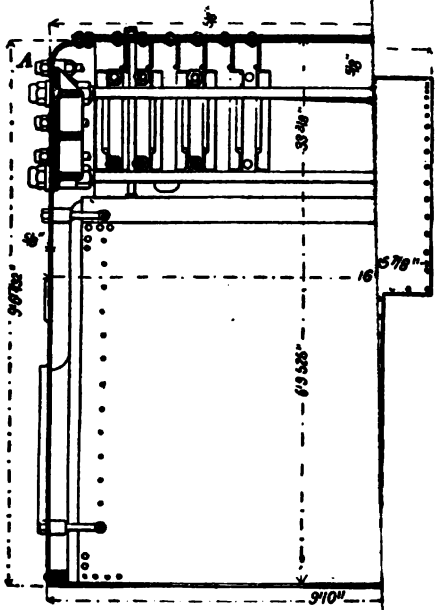
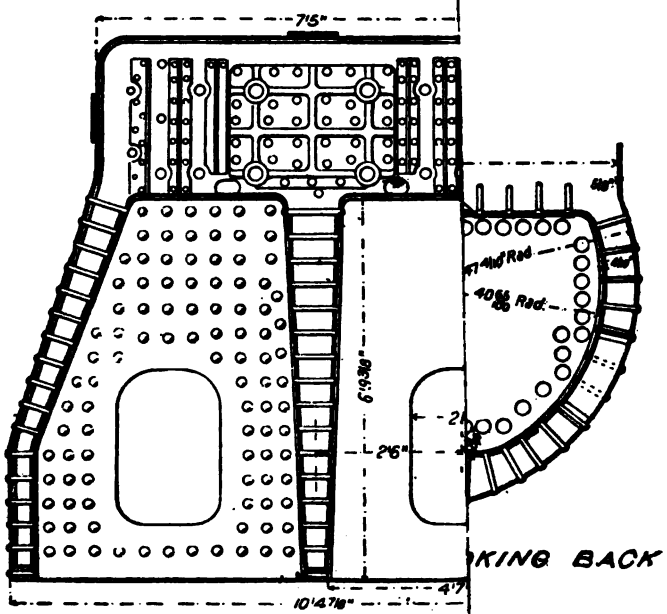


FIG.2



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pump and the small hydraulic pump, supplying oil for the hydraulic cylinder used in governing the cut-off on the high pressure engine, was also exhausted into this hot well. Ordinarily, whatever make-up was needed to supply losses was put into the hot well.

The regular feed pump (Fig. 1) *A*, which at that time was under the engine close to the hot well, took its supply from the hot well *B*. In order to weigh the air pump discharge, the piping leading from the air pump to the hot well was broken and led over to two weighing barrels *C* and *D*, each of about 1,200 pounds capacity. From a tee at the

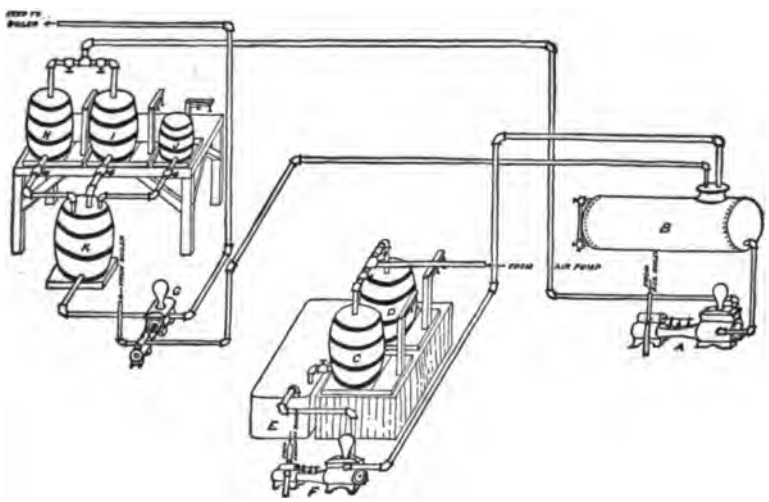

FIG. 1.

end of the air pump discharge, a branch with valve ran to each barrel, thus enabling the water to be run into first one barrel and then the other. These two barrels discharged into an open iron tank *E* of about 1,000 pounds capacity. The drips from the separator from the working sides of the first and second receivers and from the low pressure jacket were discharged after being measured into the bottom of this tank. An auxiliary pump *F*, supplied with steam from an auxiliary boiler, pumped the water from this tank into the hot well *B*. The pump *A* was disconnected from the boiler at both steam and water ends. Steam was supplied by an auxiliary boiler. It was used during the test to pump the water from the hot well to the weighing barrels *H* and *I* in the boiler room.

At first sight it might seem that there was unnecessary piping, but there appeared to be no other way of separating the different weights and at the same time getting the benefit of the heat in the exhaust steam from the feed and oil pumps. The barrels *H* and *I* were arranged similar to the barrels *C* and *D*. In these was weighed the water from the air pump plus the drips from the separator, the working sides of the first and second receivers and the low pressure jacket water, plus also the steam used by the feed pump *G* and the oil pump. The barrels *H* and *I*, together with a small make-up barrel *J* (fed from the water main), delivered into a reserve barrel *K*, from which the feed pump *G* supplied the boiler.

The returns from the high pressure, intermediate pressure, first and second reheater jackets were returned directly to the boiler by gravity, and the total amount of steam used by these was determined by a separate test made immediately after the engine test. No attempt was made to find the amount used by the different high pressure jackets separately.

At the end of the test the pipe conveying these returns to the boiler was broken and the drip turned into a closed steel reservoir about 18 inches in diameter and 9 feet tall. On the side of this reservoir were two gauge glasses, each 4 feet long, and a scale previously graduated, giving the capacity of the reservoir at any level to $\frac{1}{100}$ of a cubic foot. When full, the reservoir could be emptied quickly through a 2-inch globe valve. By noting the rate at which the reservoir filled, allowance could be made for the water lost while blowing out: From the amount caught in eighty minutes the weight for twenty-four hours was calculated.

The returns from the separator from the working sides of the two receivers and from the low pressure jacket were caught during the test in similar reservoirs made of 8-inch pipe. A throttling calorimeter with a $\frac{1}{4}$-inch steam orifice was attached to the steam pipe just before the throttle. A record was kept of the time during which the calorimeter was in use, and the amount of steam used by it was calculated by Napier's formula.

The height of water in the suction well above mean tide marsh level was read by means of a copper float and graduated scale. A scale and gauge glass on the side of one air chamber gave the level in the air chambers above mean tide marsh level. From the top of the air chamber a $\frac{1}{4}$-inch pipe led to one leg of a U tube filled with

mercury. The discharge pressure was calculated from the difference of level of the two legs of mercury. The steam used by the small engine running the scrapers in the Green economizer was run into a barrel of cold water on scales, condensed and weighed. The water pumped was measured at Fisher Hill by a weir without and contractions 10.002 feet in width. Samples of flue gas were taken just above the damper between the boiler and the economizer.

Starting and Ending the Test.

The engine was run at speed for nearly an hour before starting the boiler test. The pressure was run down, and at the time of starting the new fire was 86 pounds by the gauge. As soon as the engine was stopped, the old fire was drawn from the grate and wood previously weighed was thrown in. The boiler test was started at 8–30, the time this wood was ignited, and then the ash-pit was cleaned. As soon as the wood was well on fire, coal was thrown in, that which fell through the grates being taken out and fired again.

At 8–30 levels were noted in the boiler, in the reserve tank *K*, in the boiler room, in the iron tank *E*, into which the air pump discharge was run after being weighed, and in the hot well *B*. At the end of the boiler test these levels were made the same as at starting. At 9–09 A.M., thirty-nine minutes after starting the boiler test, the engine was started; at 9–15 the engine was running smoothly at normal speed, and the 24-hour test was begun. At 9–15 levels were noted in the boiler, in the reserve barrel *K*, in the reservoir *E*, and in the hot well *B*, and a separate record kept of the amount of water required by the boiler for twenty-four hours, and also of the steam used by the engine cylinders in twenty-four hours.

Cards from both ends of steam and water cylinders, and readings of pressures, temperatures, revolutions, etc., were taken at the stroke of a gong every fifteen minutes. Readings at the weir on Fisher Hill were taken at three or five minute intervals. After 9–15, on May 2, the end of the 24-hour engine test, the engine was run in order to drop the pressure in the boiler to that observed at starting. This result was attained at 9–26, when the engine was stopped and the boiler test ended. The fires were drawn and weighed, as were also the ashes. The jackets were in use during the entire boiler test. After ending the boiler test a new fire was built and the engine

started again. The high pressure jacket returns were now cut off from the boiler and measured as previously explained.

A second test was then made with the engine hot but not running, to see what was the rate under these conditions. The amount of drip from the low pressure cylinder jacket was also measured under the same conditions. From the rate as obtained from the second test, the amount of steam made by the boiler before the engine started was figured. The test was divided up into three watches of eight hours, thirty men working at one time. All indicator cards were planimetered and measured during the test. Corrections were determined for all thermometers used during the test. The different steam gauges were compared with an open mercury column both before and after the test. Scales were all tested in position up to 1,000 pounds, with sealed weights.

Remarks.

At the time of the test the engine was new, all bearings were slack, and previous to the test had never been run for more than seven hours consecutively. One of the firemen had never fired the boiler previous to the test, and consequently did not get best results, as is evident from the analysis of the flue gases. The excess of free oxygen shows that the fire was too thin and that too much air was admitted. This extra air carried away considerable heat which might have been saved.

At 2–06 P.M. one of the safety valves blew for four minutes. At 5–15 A.M., on May 2, one of the sections of grate fell out of the left fire-box, and in replacing it two more came out, causing the pressure to fall to 140 pounds. The bars were replaced and full pressure up again by 6 A.M. It was estimated that 200 pounds of extra coal were fired to replace this loss. This estimate was based upon the rate of firing previous to this time. The test was calculated without making any allowance for the estimated 200 pounds excess of coal, and also in items marked with the subscript *a* allowance was made.

One of the joints of the feed pump leaked slightly during the test. As soon as the leak was discovered the leakage was caught and returned to the suction barrel. From the rate of leakage it was estimated that 1,440 pounds were lost before the leak was found. There was a slight leak at the front of the boiler of which no account was taken. After the test it was discovered that there was a leakage by the low pressure piston.

Calculation of Boiler Results.

(A) Quality of steam at throttle.

Throttling calorimeter with a $\frac{1}{4}$-inch steam orifice was used. Calculated by this formula:

$$x = \frac{\lambda + .48\,(t_s - t) - q}{r}.$$

λ = total heat of saturated steam calorimeter pressure.
q = heat of liquid at temperature of entering steam.
r = total latent heat of entering steam.
t_s = temperature °F. by thermometer.
t = temperature of saturated steam at calorimeter pressure.

Time, 11–47.

Boiler pressure absolute after applying correction to gauge = 194.9.

Back pressure in calorimeter (absolute) after applying correction to gauge = 29.9.

Temperature of steam in calorimeter (corrected) = 311.0° F.

r = 845.3	q = 352.4
λ = 1,158.2	t = 250.1
t_s = 311.0	x = .988

Other values of x calculated in same way. .988 is mean of all values.

The total weight of steam used by the calorimeter in 159 minutes was figured from the flow through a $\frac{1}{4}$-inch diameter orifice by means of Napier's formula.

The average absolute boiler pressure was 191 pounds.

$$\text{Total weight} = 1{,}280 = \frac{.25 \times .25 \times .7854 \times 191 \times 159 \times 60}{70}.$$

(B) See (*l*) Boiler Test Data.

(C) Average pressure, 175.7 + 14.8 = 190.5.

Average temperature feed entering economizer = 127° F.

Heat put into one pound = $(xr + q - q)$, with xr at boiler and q feed.

149,620 (.988 × 846.85 + 350.3 − 95.1) = 163,370,078 B. T. U.

(D) See (*m*) Boiler Test Data.

(E) Total heat in one pound of wet steam as made by the boiler $= (xr + q) = (.988 \times 846.85 + 350.3) = 1{,}187$.

Returns entered boiler at 369.7° F.

Heat of liquid at this temperature = 341.9.

Heat put into this is equal to 19,587 (1,187 — 341.9) = 16,552,974 B. T. U.

(F) See (*n*) Boiler Test Data.

(G) Calculated same as (E).

$$136\ (1{,}187 - 341.9) = 114{,}934 \text{ B. T. U.}$$

(H) Found by taking the sum of (C), (E), and (G).

(I) See (*g*) Boiler Test Data.

(I_a) By deducting 200 pounds from (I).

(J) Is equal to (H) ÷ (I).

(J_a) Is equal to (H) ÷ (I_a).

(K) Found by dividing (J) by 965.8, the latent heat of steam at 212° or at atmospheric pressure.

(K_a) (J_a) ÷ 965.8.

(L) Estimated from the excess over the previous rate of firing.

(M) (I) ÷ 24.93 × 68.75.

Calculation of Engine Results and Duty.

(3) The different mean effective pressures (38, p. 88) were calculated by multiplying the total area of all the cards from one end by the spring and dividing by the total length.

The diameters of the cylinders and rods are:

High.		Intermediate.		Low.	
Piston.	Rod.	Piston.	Rod.	Piston.	Rod.
13.7	3.125	24.375	4	39	4

Stroke, 72″.

$$\text{H. P. of high pressure H. E.} = \frac{147.41 \times 59.58 \times 50.59 \times 6}{33{,}000} = 80.78.$$

$$\text{H. P. of high pressure C. E.} = \frac{139.74 \times 54.52 \times 50.59 \times 6}{33{,}000} = 70.08.$$

$$\text{H. P. of intermediate H. E.} = \frac{466.63 \times 22.61 \times 50.59 \times 6}{33{,}000} = 97.05.$$

H. P. of intermediate C. E. $= \frac{454.06 \times 21.33 \times 50.59 \times 6}{33{,}000} = 89.09.$

H. P. of low H. E. $= \frac{1{,}194.5 \times 10.66 \times 50.59 \times 6}{33{,}000} = 117.12.$

H. P. of low C. E. $= \frac{1{,}181.93 \times 11.18 \times 50.59 \times 6}{33{,}000} = 121.54.$

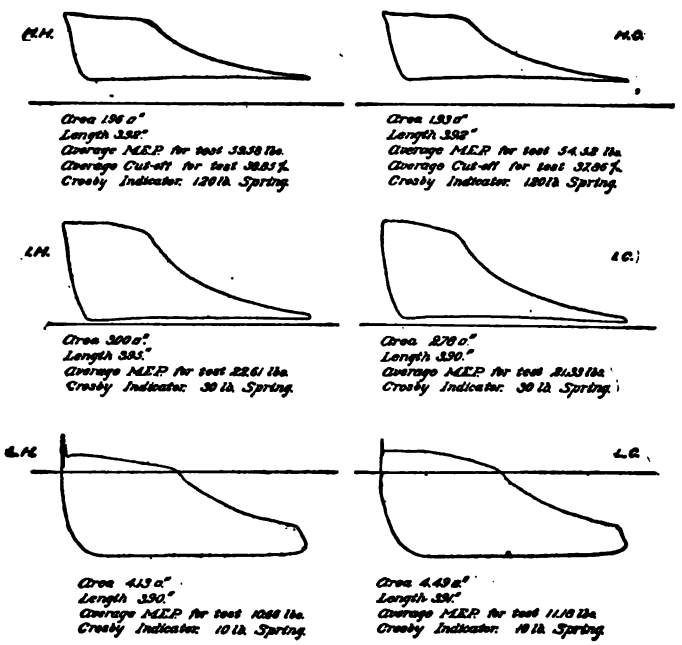

FIG. 2.

INDICATOR CARDS. CHESTNUT HILL PUMPING ENGINE. STEAM CYLINDERS.

(4) The water plungers were all 17.5″ diameter, 48″ stroke, with 3.5″ diameter piston rod. The mean effective pressures as calculated from the water cards are given in (39, p. 88). Cards marked *S* are from the end of the pump nearest the steam cylinders; those marked *P* from the opposite end.

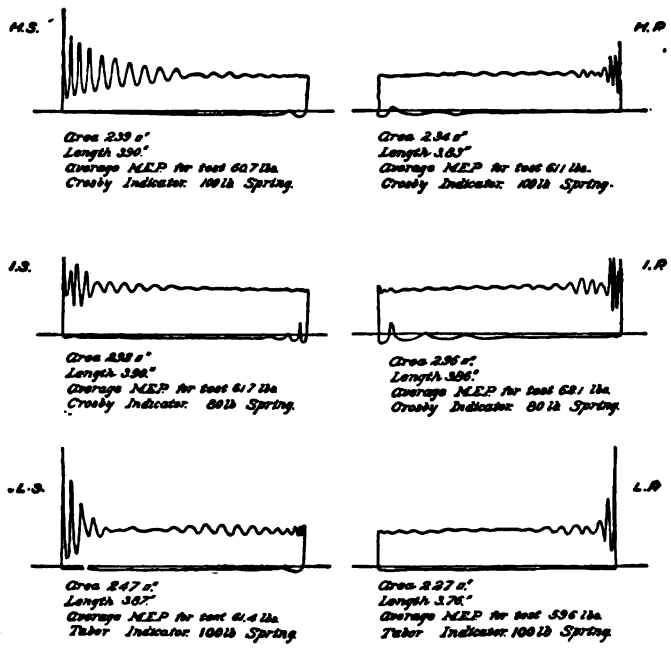

FIG. 3.

INDICATOR CARDS. CHESTNUT HILL PUMPING ENGINE. WATER CYLINDERS.

Pump opposite High.

$$\text{H. P. of S. E.} = \frac{230.90 \times 60.7 \times 50.59 \times 4}{33{,}000} = 85.95.$$

$$\text{H. P. of P. E.} = \frac{240.52 \times 61.1 \times 50.59 \times 4}{33{,}000} = 90.12.$$

Pump opposite Int.

$$\text{H. P. of S. E.} = \frac{230.90 \times 61.7 \times 50.59 \times 4}{33{,}000} = 87.36.$$

$$\text{H. P. of P. E.} = \frac{240.52 \times 62.1 \times 50.59 \times 4}{33{,}000} = 91.59.$$

Pump opposite Low.

$$\text{H. P. of S. E.} = \frac{230.90 \times 61.4 \times 50.59 \times 4}{33{,}000} = 86.94.$$

$$\text{H. P. of P. E.} = \frac{240.52 \times 59.6 \times 50.59 \times 4}{33{,}000} = 87.90.$$

(6) This is the sum of 2, 4, 5, and 13 of Engine Test Data.

(7) Sum of (5) and (6) of Engine Test Results.

(8) This is the total steam for engine cylinders and jackets for one hour divided by the total H. P. of steam cylinders.

$$\frac{155{,}043}{24 \times 575.66} = 11.22.$$

(9) The steam required for the plant for twenty-four hours, excepting that used by the high pressure jackets, is found by deducting the sum of items 7, 8, 9, 10, and 11 from item 6.

(10) $146{,}226\ (.988 \times 846.85 + 350.3 - 95.1)$
$= 159{,}664{,}169$ B. T. U.

(11) Estimated as previously explained.

(13) $19{,}370\ (1{,}187 - 341.9) = 16{,}369{,}587$ B. T. U.

(14) Sum of (10) and (13).

(15) See Boiler Test Results (J).

(16) This is found by dividing (14) by (15).

(16_a) (14) $\div$ (J_a).

(17) and (19) The water over the weir (Fig. 4, p. 115) was calculated first by the formula:

$$\text{Cu. ft. per second} = 3.33\ l h^{\frac{3}{2}}.$$

$l = 10.0026$ ft. $h = .9798$ ft., the observed height on weir.

A correction was then made for the velocity of approach. The area of a cross section of the weir at this depth was 60.3354 sq. ft.

The quantity in cubic feet per twenty-four hours was then calculated from this formula:

$$3.33\ l \left[\left(h + \frac{v^2}{2g}\right)^{\frac{3}{2}} - \left(\frac{v^2}{2g}\right)^{\frac{3}{2}}\right] 24 \times 60 \times 60 = 2{,}809{,}370 \text{ cu. ft.}$$

$$\frac{2{,}809{,}370 \times 1{,}728}{231} = 21{,}016{,}000 \text{ gallons.}$$

(20) $3 \times \frac{(230.9 + 240.52)}{144} \times 4 \times 50.59 \times 60 \times 24 = 2{,}861{,}640$ cu. ft. displacement of pump plungers.

(21) See items 33, 34, 35, 36, 37.

$$145.87 - 122.65 = 23.22 \text{ ft.}$$
$$100.88 \times .4891 \times 2.307 = 113.83.$$
$$113.83 + 23.22 = 137.05 \text{ ft. total head.}$$

The specific gravity of the mercury used was determined immediately after the test was finished. From this items 36 and 37 were calculated.

(22) This is the product of (17), (18), and (21).

(23) From items (22) and (16)

$$\frac{24,025,507,490 \times 100}{16,465} = 145,919,000.$$

(23_a) From items (22) and (16_a).

(24) (24_a) and (29).

The B. T. U. required by the engine for twenty-four hours was calculated in this way:

The total heat of the steam supplied to the cylinders above the heat of the condensed steam, plus the heat lost by the jacket steam in the high, intermediate, first and second reheater jackets, plus also the heat lost in the low pressure cylinder jackets, and in the drips from the working sides of the first and second reheaters above the heat of the liquid entering the economizer.

$$\begin{aligned} 128,471 \quad (1,187.0 - 57.3) &= 145,133,688 \\ 19,370 \times 845.1 &= 16,369,587 \\ 7,202 \times 1,091.9 &= 7,863,864 \\ &\overline{169,367,139} \end{aligned}$$

$$\frac{169,367,139}{24 \times 60 \times 575.66} = 204.3 \text{ B. T. U. per H. P. per minute.}$$

204.3 × 60 equals the B. T. U. per H. P. per hour. Divide this by the B. T. U. taken up from 1 pound of coal.

$$\frac{204.3 \times 60}{10,691.7} = 1.146. \qquad \frac{204.3 \times 60}{10,820.2} = 1.113.$$

(25) and (25_a) From (23) and (23_a) get the foot-pounds of water work done per pound of coal.

$$\frac{33{,}000 \times 60}{1{,}459{,}186} = 1.36. \qquad \frac{33{,}000 \times 60}{1{,}476{,}766} = 1.34.$$

(26) From (20) and (17)

$$\frac{2{,}861{,}640 - 2{,}809{,}370}{2{,}861{,}640} = 1.83 \text{ per cent. slip.}$$

(27) $\frac{137.05}{2.307} = 59.406$, the mean effective pressure due to head.

The H. P. of pumps calculated on this M. E. P. is

$$\frac{3 \times (240.52 + 230.9) \times 50.59 \times 59.406 \times 4}{33{,}000} = 515.19.$$

$$\frac{575.66 - 515.19}{575.66} = 10.54 \text{ per cent.}$$

(28) $100 - 10.54 = 89.46$.

(30) $\frac{33{,}000}{778} = 42.42$ B. T. U. required for one H. P.

$\frac{42.42}{204.3} = 20.76$ per cent. thermal efficiency.

(31) This is equal to the difference of absolute temperatures divided by the higher temperature:

$$\frac{(377.7 + 460.7) - (113.5 + 460.7)}{(377.7 + 460.7)} = 31.51 \text{ per cent.}$$

(32) $\frac{20.76}{31.51} = 65.9$.

(33) Duty (foot-pounds per 1,000,000 B. T. U.)

The total B. T. U. required by engine in twenty-four hours is (see calculation of (29)) 169,367,139.

$$\frac{24{,}025{,}507{,}490}{169{,}367{,}139} \times 1{,}000{,}000 = 141{,}855{,}000.$$

(34) The foot-pounds of work done per revolution as figured from the 24-hour test is equal to

$$\frac{24,025,507,490.}{72,843}$$

The total work done from the time of opening the throttle, or for 73,516 revolutions, is 24,247,503,172 foot-pounds.

The total coal burned for the entire test was 16,839 pounds.

$$\frac{24,247,503,172}{168.39} = 143,996,000.$$

$$(34_a) \qquad \frac{24,247,503,172}{166.39} = 145,727,000.$$

$$(35_a) \quad \frac{3\,(230.9 + 240.52)}{144} \times 4 \times 72,843 \times 137.05 \times 62.4 =$$

24,472,490,693 foot-pounds of work done in 24-hour test, figuring from displacements of water plungers.

$$\frac{24,472,490,693}{16,269} = 150,424,000 \text{ duty.}$$

$$(36_a) \quad \frac{3\,(230.9 + 240.52)}{144} \times 4 \times 73,516 \times 137.05 \times 62.4 =$$

24,698,595,419 foot-pounds.

$$\frac{24,698,595,419}{16,639} = 148,437,900 \text{ duty.}$$

BOILER TEST DATA.

Kind of coal, George's Creek, Cumberland.
Grate surface = 68.75 sq. ft.
Heating surface = 2,849.0 sq. ft.

Weights.

a	Weight of wood fired at starting	401.5 lbs.
b	Coal equivalent of wood	161.0 "
c	Weight of coal fired in 24.93 hours	16,734 "
d	Weight of coal fired, including coal equivalent of wood	16,895 "
e	Weight of mixture drawn from grate at end of test	224.5 "
f	Weight of good coal in this mixture	56.0 "
g	Weight of coal burned in 24.93 hours	16,839 "
h	Weight of ash, etc., from ash-pit	1,063.5 "
i	Weight of good coal in this	63 "
j	Weight of water weighed in barrels in boiler room	151,060 "
k	Weight of leakage from feed pump	1,440 "
l	Weight of water put into boiler by feed pump	149,620 "
m	Weight of water returned to boiler from high pressure jackets, engine running, as determined by separate test made immediately afterwards	19,587 "
n	Weight of water returned to boiler from high pressure jackets between time of starting boiler and of opening throttle (determined by separate test)	136 "
o	Weight of steam used by economizer scraper engine	722 "

Temperature.

	Average temperature of room	23.3° C.
	Temperature of outside air	4.2° C.
p	Temperature of gases leaving boiler and entering economizer	502° F.
q	Temperature of gases leaving economizer	233° F.
r	Temperature of feed water entering economizer	127° F.
s	Temperature of feed water leaving economizer	198.3° F.
t	Temperature of high pressure jacket returns entering boiler	369.6° F.
u	Temperature of high pressure jacket returns leaving engine	370.6° F.

Pressure.

v	Average pressure at throttle	175.7 lbs.
	Average draught pressure in inches of water	.375 in.
w	Barometer in inches of mercury, 30.25"	14.85 lbs.
x	Pressure at starting boiler test	86 "
y	Pressure at stopping boiler test	86.5 "

Time.

Time starting boiler test	8.30 A.M., May 1.
Time ending test	9.26 " "
Duration of test	24.93 hours.
Time starting engine	9.09 A.M., May 2.
Time stopping engine	9.26 " "

Detail of Heating Surface in Boiler.

Fire-boxes	288 sq. ft.	Area of grate	68.75 sq. ft.
Flues	83 "	Area of inside cross section of tubes	8.49 "
Combustion chamber	102 "	Volume of water 6" above crown sheet	617 cu. ft.
Tubes (fire side)	2,343 "	Volume of steam space, water 6" above crown sheet	416 "
Back tube sheet	33 "		
Total heating surface	2,849 sq. ft.		

ENGINE TEST DATA.

Weights.

1.	Steam through cylinders (24 hours)	128,471 lbs.
2.	Weight of drip, L. P. jacket (24 hours)	3,656 "
3.	Weight of drip, separator	585 "
4.	Weight of drip, working side, 1st receiver (24 hours)	3,118 "
5.	Weight of drip, working side, 2d receiver (24 hours)	428 "
6.	Weight of water weighed for boiler in boiler room barrels (24.93 hours)	151,060 "
7.	Make-up before starting engine test	997 "
8.	Water from engine room before starting engine test	454 "
9.	Water from engine room after ending engine test	663 "
10.	Leakage at feed pump (24 hours)	1,440 "
11.	Steam used by calorimeter	1,280 "
12.	Steam required by plant for 24 hours, except for H. P. jackets	146,226 "
13.	Weight of returns from high intermediate 1st receiver and 2d receiver jackets (24 hours)	19,370 "

Temperatures.

14.	Average temperature of engine room	23.3° C.
15.	Average temperature condensed steam leaving air pump	89.3° F.
16.	Average temperature cold condensing water	51.9° F.
17.	Average temperature hot condensing water	85.2° F.
18.	Average temperature hot well water	140.7° F.
19.	Average temperature feed water entering economizer	127.0° F.
20.	Average temperature feed water leaving economizer	198.3° F.
21.	Average temperature jacket returns entering boiler	369.6° F.

Pressures.

22.	Barometer	14.85 lbs.
23.	Pressure at throttle	175.70 "
24.	Vacuum at condenser in Ins. of Hg.	27.25
25.	Pressure in 1st receiver	46.5 lbs.
26.	Pressure in 2d receiver	2.4 "
27.	Pressure in L. P. jackets	99.6 "
28.	Pressure in H. P. jackets	175.7 "

Water.

29.	Temperature of water	52.6° F.
30.	Average height of water on weir (24 hours test)	.9798 ft.
31.	Width of weir water on weir	100,026 "
32.	Area of cross section of water in weir (24 hours test)	603,354 sq. ft.
33.	Reading suction float (feet above marsh level)	222.65 ft.
34.	Reading level in air chamber (above same level)	145.87 "
35.	Discharge pressure in Ins. of Hg.	100.88
36.	Pressure of 1 inch of Hg. 23.3° C.	.4891 lbs.
37.	Feet of water to 1 pound pressure	2.307 ft.

Steam Cards.

		H		I		L	
		H	O	H	O	H	O
38.	M. E. P.	59.58	54.52	22.61	21.33	10.66	11.18.

Water Cards.

		H		I		L	
		S	P	S	P	S	P
39.	M. E. P.	60.7	61.1	61.7	62.1	61.4	59.6.
40.	Total revolutions (24 hours)						72,843
41.	Revolutions per minute						50.59

BOILER TEST RESULTS.

(A)	Quality of steam as obtained by calorimeter at throttle of engine	.988
(B)	Total feed water put into boiler in 24.93 hours	149,620
(C)	B. T. U. put into same	163,370,078
(D)	Total return from jackets while engine was running	19,587
(E)	B. T. U. put into same	16,552,974
(F)	Total returns from jackets while engine was still	136
(G)	B. T. U. put into same	114,934
(H)	Total B. T. U. taken up from coal by water in the boiler	180,037,986
(I)	Total coal burned	16,839
(I_a)	Coal burned, allowing for 200 pounds due to dropping grate bars	16,639
(J)	B. T. U. taken up by water per pound of coal burned	10,631.7
(J_a)	(J) Allowing for 200 pounds extra coal	10,820.2
(K)	Equivalent evaporation per pound of coal from and at 212° F.	11.07
(K_a)	(K) Allowing for 200 pounds extra coal	11.20
(L)	Probable excess of coal fired due to dropping of grate bars	200
(M)	Coal per square foot of grate per hour	9.8

FLUE GAS ANALYSIS. (Average for each hour.)

	CO_2	O	CO		CO_2	O	CO
10.35–11.00	12.3	6.1	0	10.00–11.00	9.5	10.5	0
11.00–12.00	12.7	4.8	0	11.00–12.00	9.4	10.3	0.1
12.00– 1.00	11.7	5.4	0.4	12.00– 1.00	10.5	6.1	0
1.00– 2.00	12.4	5.1	0.1	1.00– 2.00	6.0	8.2	0.1
2.00– 3.00	13.1	4.4	0	2.00– 3.00	9.6	8.4	0.1
3.00– 4.00	12.3	3.8	0.3	3.00– 4.00	6.0	10.5	0.2
4.00– 5.00	11.9	5.3	0.3	4.00– 5.00	2.8	7.7	0.1
5.00– 6.00	14.5	3.8	0.1	5.00– 6.00	5.3	10.4	0
6.00– 7.00	11.7	6.6	0.3	6.00– 7.00	3.3	11.9	0.1
7.00– 8.00	8.7	9.8	0.3	7.00– 8.00	3.8	11.9	0.5
8.00– 9.00	12.5	6.5	0.2	8.00– 9.00	5.5	11.5	0
9.00–10.00	11.9	4.2	0.2				

ENGINE TEST RESULTS.

(1)	Total revolutions in 24 hours			72,843
(2)	Revolutions per minute			50.59
		H. E.	C. E.	
(3)	Total H. P. of H steam cylinder	80.78 +	70.08	150.86
	" " I steam cylinder	97.05	89.09	186.14
	" " L steam cylinder	117.12	121.54	238.66
	Total			575.66
		B.	S.	
(4)	Total H. P. of pump opposite H cylinder	90.12	85.95	176.07
	" " " I cylinder	91.59	87.36	178.95
	" " " L cylinder	87.90	86.94	174.84
	Total			529.86
(5)	Steam through cylinders in 24 hours			128,471 lbs.
(6)	Total steam through H, I, and L jackets in 24 hours, and drips from working side and jackets of reheaters			26,572 "
(7)	Total steam for engine and jackets			155,043 "
(8)	Steam per I. H. P. for steam cylinders per hour			11.22 "
(9)	Steam required by plant for 24 hours, excepting steam used by high jackets			146,226 "
(10)	B. T. U. required for the above, 146,226 ($sr + q - q$) entering economizer			159,664,169
(11)	Jacket returns to boiler in 24 hours			19,370 lbs.
(12)	Temperature of returns entering boiler			369.6° F.
(13)	B. T. U. required for above ($sr + q - q$ 369.6), 19,370			16,369,587
(14)	Total B. T. U. required by plant in 24 hours			176,033,756
(15)	B. T. U. taken up from 1 pound of coal			10,691.7
(16)	Coal required for 24 hours			16,465 lbs.
(16_a)	(16) Allowing for 200 pounds extra coal			16,269 "
(17)	Cubic feet of water over weir in 24 hours			2,809,370
(18)	Weight of 1 cubic foot of water at 52.6° F			62.4 lbs.
(19)	Capacity of pump in gallons per 24 hours at speed of 50.59 revolutions per minute (calculated from weir)			21,016,000
(20)	Displacement of pump plungers in cubic feet in 24 hours			2,861,640
(21)	Resistance overcome expressed in feet of water			137.05
(22)	Foot-pounds of water work done in 24 hours			24,025,507,490
(23)	Duty (foot-pounds of water work done for 100 pounds coal)			145,919,000
(23_a)	Duty calculated, allowing for extra coal burned due to dropping grate bars			147,677,000
(24)	Coal per steam horse power per hour (engine)			1.146 lbs.
(24_a)	(24) Allowing for 200 pounds extra coal			1.113 "
(25)	Coal per H. P. of actual water work done			1.36 "
(25_a)	Coal per H. P. of actual water work done, allowing for 200 pounds extra coal			1.34 "
(26)	Slip			1.83 per cent.
(27)	Friction of engine, pump valves, and piping up to delivery (calculating H. P. of water by taking for M. E. P. (515.19) the total head in pounds)			10.54 per cent.
(28)	Efficiency of mechanism			89.46 per cent.
(29)	B. T. U. per H. P. per minute			204.3
(30)	Thermal efficiency of engine			20.76 per cent.
(31)	Efficiency of a Carnot engine working between 175.7 pounds gauge and 27.25" vacuum,			31.51 per cent.
(32)	Per cent. efficiency of Carnot engine			65.9 per cent.
(33)	Duty (foot-pounds per 1,000,000 B. T. U.)			141,855,000
(34)	Duty calculated by taking total coal used in 24.93 hours, and the total work done by engine from time of opening throttle to time of stopping			143,996,000
(34_a)	(34) Allowing for 200 pounds excess of coal			145,727,000
(35_a)	Duty 24-hour test (figuring from displacement of water plungers, and allowing for 200 pounds excess of coal)			150,424,000
(36_a)	Duty calculated from the total displacement of water plungers from the time of opening the throttle and taking the total coal burned during the boiler test with 200 pounds allowance			148,438,000

NOTE.—(35_a) and (36_a) are given so that these results may be compared with those from other pumping engines where no weir measurements were taken and the duty figured from displacements.

STEAM CARDS. HIGH PRESSURE. Nos. 6 AND 7.

SCALE 120. CROSBY INDICATORS. (Late pattern).

Time.	Area. H. E.	Length. H. E.	Per cent. cut off. H. E.	Area. C. E.	Length. C. E.	Per cent. cut off. C. E.	Time.	Area. H. E.	Length. H. E.	Per cent. cut off. H. E.	Area. C. E.	Length. C. E.	Per cent. cut off. C. E.
9.15	1.83	3.94	37.5	1.73	3.97	40.7	10.15	1.97	3.95	38.5	1.88	3.88	37.0
9.30	1.89	3.92	38.5	1.81	3.88	37.7	10.30	1.96	3.94	40.0	1.91	3.93	37.0
9.45	1.94	3.96	38.3	1.90	3.96	36.0	10.45	1.95	3.91	40.0	1.87	3.90	37.5
10.00	1.93	3.91	37.2	1.88	3.92	36.0	11.00	1.99	3.93	37.0	1.91	3.90	37.0
10.15	1.94	3.90	37.5	1.84	3.91	37.7	11.15	1.95	3.93	39.0	1.89	3.95	37.5
10.30	1.96	3.91	38.2	1.88	3.92	36.75	11.30	1.95	3.95	37.5	1.90	3.93	38.0
10.45	1.96	3.93	39.0	1.89	3.95	37.25	11.45	1.97	3.93	38.0	1.92	3.90	37.0
11.00	1.96	3 92	40.3	1.83	3.92	37.5	12.00	2.00	3.90	39.5	1.88	3.87	37.6
11.15	1.96	3.92	39.3	1.84	3.92	37.0	12.15	1.96	3.93	40.5	1.89	3.94	37.5
11.30	1.97	3.92	39.0	1.85	3.92	37.5	12.30	1.94	3.93	39.5	1.88	3.86	37.0
11.45	1.95	3.93	40.5	1.90	3.92	38	12.45	1.99	3.92	40.0	1.89	3.92	37.5
12.00	1.95	3.92	38.2	1.89	3.93	38	1.00	1.97	3.94	40.0	1.91	3.96	38.0
12.15	1.96	3.90	38 0	1.91	3 90	39 5	1.15	1.95	3.94	37.0	1.92	3.90	36.0
12.30	1.92	3.93	39 0	1.93	3.95	38.25	1.30	1.97	3.94	38.5	1.92	3.91	38.0
12.45	1.98	3.93	39.0	1.85	3.96	37.0	1.45	1.93	3.93	40.5	1.90	3.92	40.5
1.00	1.98	3.88	39.2	1.90	3.93	37.7	2.00	1.94	3.92	38.25	1.90	3.94	37.5
1.15	1.99	3.93	38.0	1.89	3.91	37.7	2.15	1.98	3.89	35 0	1.91	3.95	38.0
1.30	1.98	3.94	38.5	1.89	3 90	37.0	2.30	1.99	3.93	38.0	1.92	3.93	37.5
1.45	1.97	3.89	39.2	1.89	3.92	36.0	2.45	1.95	3.92	39.5	1.91	3.94	37.0
2.00	1.98	3.94	39 2	1.88	3.97	38.2	3.00	1.98	3.91	37.5	1 91	3.91	37.0
2.15	1.95	3.93	38.5	1.91	3.92	37.5	3.15	1.98	3.93	39.0	1.92	3.94	37.5
2.30	1.97	3.92	38.5	1.87	3.93	38.2	3.30	1.94	3.94	37.0	1.92	3.91	38.0
2.45	1.97	3.94	39.0	1.94	3.93	37.0	3.45	1.99	3.93	39.0	1.92	3.90	37.0
3.00	1.94	3.91	38.5	1.90	3.92	38.25	4.00	1.97	3.92	38.0	1.90	3.92	37.0
3.15	1.98	3.90	38.5	1.89	3 94	37.5	4.15	1.97	3.91	38.0	1.91	3.91	37.0
3.30	1.96	3.88	38.5	1.93	3.94	37.5	4.30	1.95	3.92	38.5	1.91	3.91	....
3.45	1.95	3.90	38.0	1.95	3.94	38.0	4.45	1.97	3.93	37.5	1.92	3.94	38.0
4.00	1.96	3.90	37.75	1.92	3.92	37.75	5.00	1.98	3.92	40.0	1.92	3.96	38.0
4.15	1.98	3.90	38 5	1.82	3.91	37.0	5.15	1.96	3.93	38 5	1.91	3 91	38.5
4.30	1.97	3 97	37.5	1.91	3.93	37.5	5.30	1.54	3.92	54.5	1.54	3.97	54.0
4.45	2.01	3.92	38 0	1.91	3 91	36.5	5.45	1.68	3.93	38.0	1.70	3.97	47.0
5.00	1.98	3.88	38.0	1.92	3.90	36.0	6.00	1.96	3.97	39.0	1.94	3.90	37.0
5.15	1.96	3.92	39.0	1.93	3.92	38.0	6.15	1.97	3.91	39.0	1.95	3.94	38.5
5.30	1.97	3.93	38.8	1.90	3.92	36.5	6.30	1.96	3.92	39.0	1.95	3.95	38.5
5.45	1.97	3.91	38 8	1.90	3.92	31.0	6.45	1.95	3.92	34.5	1.92	3.92	36.5
6.00	1.97	3.90	35.0	1.89	3.94	37.5	7.00	1.95	3.91	37.0	1.94	3.93	36.5
6.15	2.00	3.94	39.0	1.91	3.90	32.0	7.15	1.96	3.92	38.0	1.91	3.90	37.0
6.30	1.95	3.90	36.5	1.90	3.94	37.0	7.30	2.00	3.90	40.5	1.95	3.96	37.0
6.45	2.00	3.92	39.3	1.92	3.94	37.0	7.45	2.00	3.93	39 0	1.95	3.94	37.0
7.00	1.94	3.92	38.0	1.88	3.90	37.0	8.00	1.98	3.96	38.0	1.94	3.94	38.0
7.15	1.98	3.94	39.0	1.90	3.92	38.0	8.15	1.98	3.91	40.0	1.95	3.94	39.0
7.30	1 91	3.88	36.5	1.91	3.92	37.0	8.30	1.99	3.91	38.0	1.95	3.95	36.5
7.45	1.99	3.92	39.0	1.88	3.86	37.5	8.45	1.97	3.93	38.5	1.95	3.93	38.0
8.00	2.03	3.93	39.5	1.92	3.92	37.5	9.00	1.78	3.93	45.0	1.74	3.91	45.0
8.15	1.95	3.86	38.0	1.87	3.88	36.5	9.15	1.09	3.90	73.5	1.10	3.79	73.0
8.30	2.03	3.88	39.0	1.87	3 90	36.5							
8 45	1.95	3.92	38.5	1.88	3.89	38 5							
9.00	1.97	3.89	38.0	1.89	3.92	38.0	Total,	188.80	380.26	3,768.70	172.83	380.39	3,634.85
9.15	2.00	3.91	18.0	1.90	3.92	36.5							
9.30	1.95	3.92	37.0	1.90	3.91	37.0							
9.45	1.95	3 92	38.0	1.89	3.89	39.0	Av. =			38.85%		Av. =	37.86%
10.00	1.95	3.94	39.5	1.91	3.95	37.8							

STEAM CARDS. INTERMEDIATE. Nos. 8 and 9.

Scale 30. Crosby Indicators.

Time.	Area. H. E.	Length. H. E.	Area. C. E.	Length. C. E.	Time.	Area. H. E.	Length. H. E.	Area. C. E.	Length. C. E.
9.15	2.98	3.88	2.87	3.98	9.45	2.98	3.93	2.82	3.99
9.30	2 98	3.90	2.80	3.98	10.00	2.85	3.94	2.80	3.96
9.45	2.96	3.94	2.82	3.96	10.15	2.91	3.92	2.80	3.99
10:00	2.91	3.81	2.83	3.98	10.30	2.96	3.95	2.79	3.99
10.15	3.03	3.88	2.86	3.96	10.45	2.96	3.95	2.77	3.98
10.30	3.01	3.91	2 80	3.98	11.00	3.02	3.92	2.82	4.00
10.45	3.00	3.91	2.80	3.98	11.15	3.04	3.91	2.81	3.96
11.00	2.99	3.90	2.80	3.97	11 30	3.03	3.92	2.82	3.97
11.15	2.96	3.90	2.80	3.98	11.45	2.98	3.95	2.82	3 97
11.30	3.02	3.92	2.77	3.99	12.00	2.99	3.94	2.78	3.97
11.45	3.01	3.90	2.74	3.98	12.15	3.00	3.95	2.82	3.96
12.00	2.98	3.90	2.77	3.88	12.30	2.94	3.98	2.86	3.98
12.15	2.95	3.92	2.72	3.88	12.45	2.98	3.94	2.80	3.98
12.30	2.97	3.90	2.78	3.96	1.00	2.97	3.92	2.84	3.98
12.45	3.00	3.91	2.80	3.97	1.15	2.80	3.94	2.75	3.98
1.00	2.95	3.94	2.78	3.98	1.30	2.98	3.90	2.78	3.97
1.15	2.98	3.93	2.78	3.98	1.45	3 00	3.94	2.80	3.99
1.30	2.91	3.92	2.76	3.99	2.00	3.02	3.82	2.82	3.98
1.45	2.90	3.95	2.78	3.98	2.15	2.97	3.92	2.80	3.99
2.00	2.93	3.95	2.80	3.98	2.30	3.00	3.93	2.86	4.00
2.15	2.91	3.96	2.81	3.99	2.45	3.01	3.94	2.82	3.97
2.30	2.93	3.95	2.79	3.97	3.00	3.00	3.94	2.74	3.98
2.45	2.93	3.94	2.80	4.00	3.15	3.00	3.95	2.82	4.00
3.00	2.97	3.97	2.80	3.97	3.30	2.95	3.92	2.83	3.96
3.15	2.93	3.95	2.79	3.98	3.45	3.00	3.94	2.88	3.98
3.30	2.93	3.97	2 80	3.98	4.00	2.99	3.92	2.84	3.96
3.45	2.97	3.94	2.80	3 99	4.15	2.98	3.93	2.81	3.97
4.00	2 97	3.96	2.80	3.98	4.30	2.96	3.94	2.86	3.96
4.15	2.96	3.94	2.81	3.95	4.45	2.93	3.94	2.79	3.96
4.30	2 95	3.97	2.81	3.98	5.00	2 94	3.95	2.88	3.98
4.45	3.04	3.95	2.79	3.97	5.15	3.00	3.94	2.80	3.95
5.00	3.00	3.95	2.81	3.96	5.30	3.24	3.94	3.06	3.99
5.15	3.00	3.95	2.78	3.90	5.45	3.17	3.95	3.08	3.95
5.30	2.97	3.95	2.84	3.98	6.00	3.06	3.95	2.90	3.95
5.45	2.97	3.96	2.83	3.97	6.15	2.95	3.96	2.88	3.98
6.00	2.95	3.95	2.81	3.97	6.30	2.95	3.94	2.90	3.98
6.15	2.95	3.98	2.81	3.98	6.45	2.85	3.95	2.75	3.99
6.30	2.90	3.94	2.81	3.97	7.00	2.82	3.95	2.68	4.00
6.45	2.93	3.93	2.82	3.97	7.15	2.85	3.96	2.75	3.97
7.00	2.93	3.92	2.80	3.98	7.30	2.97	3.96	2.82	4.00
7.15	2.94	3.96	2.83	3.98	7 45	2.95	3.94	2.84	3.98
7.30	2.93	3.93	2.84	3.99	8.00	3.03	3.97	2.94	3.99
7.45	2.97	3.97	2.81	3.96	8.15	2.97	3.96	2.83	3.98
8.00	2.91	3.93	2.81	3.96	8.30	2.94	3.95	2.86	3.97
8.15	2.99	3.92	2.86	3.99	8 45	2.94	3.95	2.90	3.98
8.30	2.96	3.94	2.84	3.98	9.00	3.10	3.95	3.00	3.98
8.45	2.95	3.96	2.80	3.97	9.15	3.54	3.96	3.40	3.99
9.00	2.95	3.95	2.82	3.98					
9.15	2.95	3.67	2.81	3.94					
9.30	2.94	3.93	2.82	3.97	Total,	288.47	381.78	274.03	385.45

STEAM CARDS. LOW PRESSURE. Nos. 10 and 11.

Scale 10. Crosby Indicators.

Time.	Area. H. E.	Length. H. E.	Area. C. E.	Length. C. E.	Time.	Area. H. E.	Length. H. E.	Area. C. E.	Length. C. E.	Time.	Area. H. E.	Length. H. E.	Area. C. E.	Length. C. E.
9.15	4.42	3.90	....	....	5.30	4.14	3.87	4.48	3.90	1.45	4.20	3.94	4.44	3.93
9.30	4.16	3.90	4.28	3.98	5.45	4.16	3.88	4.38	3.91	2.00	4.09	3.90	4.47	3.91
9.45	4.23	3.91	4.26	3.82	6.00	4.14	3.87	4.36	3.92	2.15	4.13	3.90	4.31	3.92
10.00	4.23	3.91	4.25	3.81	6.15	4.17	3.89	4.47	3.92	2.30	4.13	3.90	4.49	3.91
10.15	4.23	3.91	4.20	3.99	6.30	4.15	3.90	4.45	3.92	2.45	4.10	3.90	4.45	3.90
10.30	4.18	3.92	4.15	3.82	6.45	4.22	3.88	4.39	3.98	3.00	4.12	3.90	4.39	3.90
10.45	4.23	3.94	4.25	3.94	7.00	4.20	3.92	4.30	3.90	3.15	4.14	3.87	4.35	3.89
11.00	4.23	3.92	4.23	3.84	7.15	4.16	3.90	4.39	3.94	3.30	4.09	3.90	4.38	3.90
11.15	4.20	3.90	4.23	3.91	7.30	4.17	3.91	4.35	3.92	3.45	4.17	3.90	4.37	3.88
11.30	4.22	3.90	4.22	3.83	7.45	4.14	3.87	4.36	3.90	4.00	4.12	3.89	4.31	3.86
11.45	4.17	3.91	4.22	3.91	8.00	4.18	3.90	4.48	3.92	4.15	4.08	3.89	4.39	3.92
12.00	4.46	4.02	4.23	3.90	8.15	4.15	3.90	4.39	3.93	4.30	4.13	3.90	4.29	3.88
12.15	4.21	3.90	4.39	3.97	8.30	4.21	3.92	4.39	3.92	4.45	4.12	3.90	4.35	3.95
12.30	4.13	3.88	4.40	4.04	8.45	4.16	3.90	4.34	3.95	5.00	4.12	3.91	4.36	3.93
12.45	4.14	3.91	4.38	3.98	9.00	4.16	3.88	4.39	3.91	5.15	4.08	3.89	4.28	3.86
1.00	4.15	3.88	4.39	4.01	9.15	4.14	3.87	4.40	3.91	5.30	4.38	3.89	4.51	3.87
1.15	4.16	3.88	4.41	3.98	9.30	4.14	3.89	4.38	3.95	5.45	4.30	3.88	4.56	3.93
1.30	4.16	3.89	4.42	3.96	9.45	4.22	3.88	4.39	3.91	6.00	4.11	3.90	4.39	4.01
1.45	4.08	3.87	4.43	3.95	10.00	4.12	3.99	4.41	3.92	6.15	4.08	3.89	4.35	3.90
2.00	4.18	3.92	4.45	3.92	10.15	4.12	3.85	4.47	3.95	6.30	4.06	3.89	4.28	3.90
2.15	4.14	3.90	4.44	3.90	10.30	4.10	3.89	4.38	3.92	6.45	3.96	3.88	4.25	3.93
2.30	4.22	3.95	4.41	3.99	10.45	4.16	3.91	4.44	3.92	7.00	3.95	3.90	4.20	3.98
2.45	4.16	3.90	4.40	3.93	11.00	4.16	3.88	4.40	3.91	7.15	3.96	3.90	4.27	3.97
3.00	4.16	3.89	4.45	3.91	11.15	4.16	3.90	4.53	3.94	7.30	4.15	3.89	4.33	3.91
3.15	4.22	3.92	4.40	3.90	11.30	4.15	3.89	4.48	3.95	7.45	4.12	3.90	4.35	3.90
3.30	4.15	3.89	4.42	3.91	11.45	4.17	3.88	4.40	3.90	8.00	4.03	3.88	4.33	3.92
3.45	4.16	3.88	4.43	3.94	12.00	4.18	3.90	4.46	3.94	8.15	4.11	3.94	4.35	3.90
4.00	4.14	3.88	4.40	3.90	12.15	4.18	3.89	4.39	3.92	8.30	4.03	3.88	4.36	3.94
4.15	4.14	3.90	4.39	3.92	12.30	4.17	3.90	4.45	3.90	8.45	4.02	3.90	4.33	3.91
4.30	4.14	3.92	4.41	3.91	12.45	4.16	3.90	4.51	3.95	9.00	4.16	3.87	4.49	3.95
4.45	4.13	3.88	4.42	3.94	1.00	4.18	3.90	4.45	3.94	9.15	4.71	3.86	4.95	3.97
5.00	4.05	3.86	4.39	3.90	1.15	4.07	3.90	4.35	3.90					
5.15	4.06	3.87	4.41	3.93	1.30	4.16	3.92	4.42	3.95	Totals,	403.24	378.08	420.72	376.49

TEMPERATURES.

Time.	Temperature first receiver. °F.	Temperature second receiver. °F.	H. P. jacket returns at engine. °F.	Time.	Temperature first receiver. °F.	Temperature second receiver. °F.	H. P. jacket returns at engine. °F.	Time.	Reading temperature room. °C.	Time.	Reading temperature room. °C.
9.15	319	305	370	12.15	320	308	372	12.30	24.5	3.00	22.4
10.15	320	309	370	1.15	320	308	372	1.30	24.4	4.00	22.1
11.15	322	296	370	2.15	320	308	372	2.00	24	5.00	21.9
12.15	322	306	372	3.15	319	306	372	3.00	24.8	6.00	22.0
1.15	322	308	370	4.15	319	306	372	4.00	25.4	7.00	22.0
2.15	322	309	370	6.15	319	306	371	5.00	25.0	8.00	21.4
3.15	322	309	370	7.15	319	306	372	6.00	24.1	9.00	23.0
4.15	322	309	370	8.15	319	306	372	7.00	24.2		
5.15	320	308	372	9.15	318	304	371	8.00	24.0		
6.15	320	308	372	....	308	282	334	9.00	23.3	Total,	5,126
7.15	320	308	372					10.00	23.3		
8.15	320	308	372					11.00	23.2	Av.,	23.3°C.
9.15	320	308	372	Total,	7,992	7,647	9,246	12.00	22.8		
10.15	320	308	372					1.00	22.5		
11.15	320	308	372	Av.,	319.7	305.9	370.6	2.00	22.3		

WATER CARDS. Nos. 12 to 17.

SPRINGS 100 AND 80. CROSBY INDICATORS ON ALL BUT L. S. AND L. P.

Time.	Area. H. S.	Length. H. S.	Area. H. P.	Length. H. P.	Area. I. S.	Length. I. S.	Area. I. P.	Length. I. P.	Area. L. S.	Length. L. S.	Area. L. P.	Length. L. P.
9.15	....	....	....	....	2.92	3.86	2.97	3.86	2.47	3.87	2.26	3.80
9.30	2.17	3.56	2.20	3.88	2.94	3.87	2.96	3.86	2.38	3.87	2.27	3.76
9.45	2.16	3.59	2.36	3.84	3.00	3.92	2.99	3.88	2.35	3.86	2.26	3.73
10.00	2 39	3.90	2.34	3.83	2.95	3.88	2.94	3.85	2.34	3.87	2.26	3.76
10.15	2.36	3.88	2.34	3.88	3.00	3.88	3.01	3.86	2.37	3.87	2.30	3.74
10.30	2.41	3.90	2.38	3.90	3.02	3.88	2.96	3.86	2.36	3.88	2.24	3.73
10.45	2.30	3.88	2.34	3.88	2.97	3.88	2.97	3.86	2.36	3.87	2.26	3.73
11.00	2.34	3.88	2.34	3.88	3.00	3.90	2.95	3.86	2.38	3.87	2.28	3.73
11.15	2.41	3.88	2.35	3.87	3.01	3.90	3.00	3.86	2.37	3.86	2.26	3.73
11.30	2.36	3.88	2.34	3.88	2.97	3.86	2.97	3 84	2.35	3.87	2.24	3.73
11.45	2.38	3.88	2.37	3.88	3.16	3.87	2.96	3.86	2.39	3.90	2.28	3.73
12.00	2.34	3.88	2.36	3.88	3.03	3.88	3.00	3.87	2.40	3.86	2.29	3.72
12.15	2.41	3.88	2.32	3 86	2.94	3.86	2.99	3.88	2.36	3.87	2.28	3.73
12.30	2.34	3.88	2.36	3.87	2.98	3.89	2.97	3.86	2.38	3.86	2.28	3.73
12.45	2.41	3.88	2.39	3.88	3.02	3.85	3.01	3.86	2.34	3.87	2.29	3.71
1.00	2.41	3.88	2.31	3.88	2.97	3.88	2.94	3.86	2.36	3.86	2.26	3.73
1.15	2.38	3.90	2.34	3.86	3.00	3.88	2.95	3.86	2.36	3.86	2.24	3.73
1.30	2.33	3.90	2.35	3.86	3.05	3.88	2.98	3 88	2.38	3.87	2.26	3.73
1.45	2.39	3.90	2.33	3.82	3.06	3.87	2.96	3.84	2.36	3.86	2.22	3.73
2.00	2.41	3.90	2.37	3.83	3.01	3.86	2.98	3.86	2.36	3.86	2.24	3.73
2.15	2 42	3.90	2.30	3.84	2.99	3.88	3.00	3.86	2.35	3.86	2.26	3.73
2.30	2.39	3.90	2.39	3.84	2.93	3.87	2.92	3.80	2.39	3.87	2.22	3.73
2 45	2.39	3.90	2.34	3.85	2.96	3.88	2.92	3.84	2.37	3.86	2.25	3.73
3.00	2.39	3.90	2.50	3.90	2.98	3.88	3.00	3.86	2.35	3.86	2.28	3.73
3.15	2.41	3.90	2.30	3.84	2.95	3.88	2.98	3.86	2.36	3.86	2.25	3.73
3.30	2.41	3.90	2.38	3.84	3.08	3.88	2.96	3.86	2.37	3.86	2.26	3.73
3.45	2.39	3.90	2.34	3.80	2.97	3.86	2.97	3.86	2.37	3.86	2.28	3.73
4.00	2.41	3.90	2.30	3.84	2.93	3.86	2.98	3 86	2.36	3.87	2.29	3.72
4.15	2.36	3.90	2.33	3.83	2.94	3.86	2.95	3.86	2.35	3.87	2.30	3.74
4.30	2.32	3.89	2.33	3 84	2.96	3.86	2.97	3.88	2.39	3.85	2.20	3.71
4.45	2.38	3.89	2 40	3.82	2.97	3.88	2.98	3.86	2.50	3.84	2.37	3.70
5.00	2.43	3.86	2.34	3.81	2.90	3.84	2.98	3.82	2.29	3.84	2.20	3.70
5.15	2.33	3.86	2.34	3.81	2.99	3.86	2.95	3.84	2.31	3.82	2.36	3.70
5.30	2.39	3.90	2.35	3.82	3.01	3.89	2.93	3.84	2.38	3.86	2.23	3.70
5.45	2.38	3 87	2.34	3 82	2.97	3.88	2 99	3.86	2.35	3.86	2.15	3.70
6.00	2.40	3.87	2.35	3.83	3.04	3.89	2.97	3.82	2.40	3.84	2.27	3.72
6.15	2.34	3.88	2.34	3.82	3.02	3.89	2.89	3.82	2.31	3.86	2.25	3.69
6.30	2.37	3.88	2 32	3.81	3.01	3.87	2.94	3.82	2.33	3.86	2.15	3.64
6.45	2.32	3.87	2.35	3.84	3.02	3.88	2 98	3.82	2.35	3.86	2.30	3.72
7.00	2.38	3.88	2.34	3.83	3.10	3.89	2.99	3.82	2.40	3.86	2.28	3.69
7.15	2 34	3.88	2.31	3.83	2.97	3.90	2.98	3.86	2.30	3.86	2.26	3.68
7.30	2.37	3.88	2.32	3.83	2.96	3.88	2.95	3.82	2.31	3.86	2.19	3.66
7.45	2.36	3.88	2.35	3.84	3.03	3.90	2.98	3.86	2.37	3.86	2.21	3.66
8.00	2.37	3.87	2.30	3.82	3.01	3.87	3.02	3.86	2.40	3.86	2.26	3.67
8.15	2.40	3.86	2.39	3.82	2.99	3.92	2.95	3.84	2.34	3.84	2.20	3.64
8.30	2.36	3.90	2.40	3.83	3.14	3 96	2.94	3.83	2.41	3.86	2.14	3.66
8.45	2.40	3.88	2.35	3.82	2.99	3.86	2.98	3.83	2.30	3.86	2.26	3.66
9.00	2.39	3.89	2.34	3.82	3.00	3.91	2.97	3.83	2.45	3.87	2.24	3.68
9.15	2.32	3.86	2.36	3.82	2.93	3.86	2.98	3.84	2.31	3.84	2.15	3.65
9.30	2.31	3.87	2.35	3.82	3.01	3.84	2.96	3.83	2.40	3.84	2.18	3.66
9.45	2.32	3.87	2.30	3.82	2.99	3.88	2.91	3.83	2.39	3.84	2.18	3.66

WATER CARDS. Nos. 12 to 17. — *Continued.*

Springs 100 and 80. Crosby Indicators on all but L. S. and L. P.

Time.	Area. H. S.	Length. H. S.	Area. H. P.	Length. H. P.	Area. I. S.	Length. I. S.	Area. I. P.	Length. I. P.	Area. L. S.	Length. L. S.	Area. L. P.	Length. L. P.
10.00	2.34	3.86	2.30	3.81	2.92	3.86	2.95	3.83	2.34	3.84	2.18	3.64
10.15	2.32	3.86	2.34	3.82	3.02	3.87	2.96	3.83	2.40	3.86	2.21	3.64
10.30	2.32	3.86	2.35	3.82	3.01	3.89	2.95	3.83	2.34	3.84	2.19	3.65
10.45	2.33	3.86	2.33	3.80	3.00	3.90	2.97	3.84	2.35	3.84	2.10	3.64
11.00	2.32	3.86	2.35	3.80	2.99	3.90	3.01	3.85	2.35	3.88	2.20	3.66
11.15	2.36	3.87	2.35	3.81	2.97	3.88	3.01	3.83	2.44	3.87	2.22	3.65
11.30	2.39	3.90	2.41	3.80	3.06	3.86	3.00	3.84	2.28	3.86	2.19	3.63
11.45	2.37	3.89	2.31	3.80	2.91	3.87	2.98	3.84	2.38	3.86	2.17	3.60
12.00	2.40	3.90	2.38	3.80	3.06	3.88	2.98	3.84	2.31	3.86	2.20	3.64
12.15	2.31	3.88	2.34	3.82	2.96	3.92	3.01	3.85	2.42	3.88	2.07	3.50
12.30	2.39	3.88	2.38	3.80	3.11	3.87	2.99	3.84	2.83	3.84	2.13	3.50
12.45	2.28	3.74	2.38	3.82	3.06	3.87	3.04	3.84	2.50	3.87	2.14	3.50
1.00	2.30	3.88	2.32	3.80	2.95	3.88	3.10	3.84	2.26	3.86	2.02	3.48
1.15	2.31	3.84	2.35	3.80	2.85	3.83	3.00	3.82	2.34	3.88	2.11	3.50
1.30	2.25	3.74	2.33	3.82	2.95	3.92	3.02	3.82	2.41	3.88	2.11	3.48
1.45	2.40	3.92	2.33	3.82	3.03	3.96	2.99	3.84	2.35	3.87	2.02	3.40
2.00	2.38	3.90	2.35	3.80	3.03	3.96	3.03	3.85	2.34	3.88	1.94	3.42
2.15	2.36	3.90	2.33	3.82	3.01	3.93	3.05	3.85	2.32	3.88	2.06	3.42
2.30	2.36	3.92	2.34	3.82	3.08	3.97	3.02	3.84	2.36	3.87	1.93	3.39
2.45	2.37	3.90	2.34	3.82	2.95	3.96	2.99	3.84	2.36	3.88	2.02	3.40
3.00	2.34	3.90	2.35	3.82	3.00	3.94	3.00	3.86	2.37	3.88	2.04	3.36
3.15	2.38	3.88	2.32	3.80	2.98	3.96	3.01	3.82	2.44	3.87	2.15	3.58
3.30	2.39	3.90	2.32	3.80	2.92	3.95	2.99	3.83	2.42	3.87	2.11	3.60
3.45	2.42	3.92	2.33	3.80	2.94	3.97	3.04	3.84	2.40	3.87	2.09	3.60
4.00	2.32	3.92	2.38	3.80	3.01	3.97	3.04	3.82	2.36	3.86	2.18	3.60
4.15	2.34	3.90	2.36	3.80	3.03	3.94	3.04	3.84	2.39	3.88	2.10	3.62
4.30	2.36	3.90	2.40	3.80	2.99	3.96	2.95	3.82	2.36	3.87	2.14	3.54
4.45	2.37	3.92	2.31	3.80	3.00	3.95	2.95	3.85	2.33	3.88	2.15	3.52
5.00	2.34	3.92	2.31	3.80	3.09	3.92	3.01	3.82	2.40	3.87	2.12	3.50
5.15	2.37	3.90	2.32	3.80	2.98	3.97	2.96	3.84	2.40	3.88	2.07	3.52
5.30	2.38	3.90	2.32	3.82	2.98	3.88	2.98	3.82	2.40	3.88	2.11	3.54
5.45	2.39	3.94	2.32	3.78	3.02	3.88	3.01	3.82	2.40	3.87	2.18	3.52
6.00	2.34	3.90	2.35	3.78	2.97	3.86	3.02	3.82	2.40	3.85	2.12	3.52
6.15	2.34	3.90	2.31	3.80	3.01	3.88	2.96	3.84	2.42	3.86	2.18	3.54
6.30	2.37	3.90	2.30	3.80	3.10	3.88	2.98	3.84	2.41	3.86	2.11	3.54
6.45	2.32	3.90	2.30	3.80	2.98	3.92	2.94	3.84	2.32	3.86	2.11	3.50
7.00	2.29	3.90	2.28	3.80	2.85	3.92	2.95	3.82	2.30	3.86	2.06	3.52
7.15	2.30	3.90	2.26	3.80	2.95	3.91	2.94	3.84	2.26	3.86	2.14	3.53
7.30	2.42	3.90	2.31	3.82	3.14	3.94	3.02	3.85	2.40	3.87	2.00	3.44
7.45	2.36	3.90	2.34	3.82	3.14	3.92	3.00	3.84	2.38	3.88	2.06	3.52
8.00	2.34	3.90	2.30	3.80	3.13	3.92	3.00	3.83	2.36	3.86	2.08	3.48
8.15	2.34	3.90	2.30	3.80	3.15	3.94	3.02	3.85	2.43	3.85	2.10	3.40
8.30	2.38	3.90	2.30	3.80	3.14	3.92	3.04	3.84	2.38	3.86	2.12	3.44
8.45	2.35	3.92	2.30	3.80	3.03	3.92	3.02	3.84	2.40	3.87	2.08	3.50
9.00	2.37	3.90	2.30	3.78	3.11	3.90	3.00	3.82	2.34	3.86	1.90	3.44
9.15	2.38	3.88	2.32	3.78	3.11	3.93	2.96	3.83	2.40	3.86	2.08	3.40
Total,	226.41	372.48	224.46	367.16	291.41	377.84	289.21	372.85	230.07	209.48	209.48	351.24
M. E. P.	60.7		61.1		61.7		61.1		61.4		59.6	

SUCTION LIFT. No. 1.

Time.	Reading.	Time.	Reading.	Time.	Reading.	Time.	Reading.	Time.	Reading.	Time.	Reading.
9.15	122.56	1.30	122.46	5.45	122.47	10.00	122.70	2.15	122.80	6.30	122.82
9.30	122.46	1.45	122.46	6.00	122.47	10.15	122.76	2.30	122.77	6.45	122.77
9.45	122.46	2.00	122.46	6.15	122.66	10.30	122.75	2.45	122.82	7.00	122.83
10.00	122.51	2.15	122.47	6.30	122.70	10.45	122.72	3.00	122.82	7.15	122.84
10.15	122.50	2.30	122.47	6.45	122.66	11.00	122.76	3.15	122.80	7.30	122.85
10.30	122.47	2.45	122.47	7.00	122.67	11.15	122.77	3.30	122.86	7.45	122.74
10.45	122.47	3.00	122.47	7.15	122.67	11.30	122.80	3.45	122.79	8.00	122.70
11.00	122.47	3.15	122.47	7.30	122.65	11.45	122.77	4.00	122.87	8.15	122.64
11.15	122.46	3.30	122.47	7.45	122.64	12.00	122.73	4.15	122.86	8.30	122.66
11.30	122.46	3.45	122.47	8.00	122.69	12.15	122.75	4.30	122.79	8.45	122.62
11.45	122.46	4.00	122.47	8.15	122.66	12.30	122.84	4.45	122.86	9.00	122.60
12.00	122.46	4.15	122.47	8.30	122.68	12.45	122.75	5.00	122.81	9.15	122.66
12.15	122.46	4.30	122.47	8.45	122.68	1.00	122.74	5.15	122.86		
12.30	122.46	4.45	122.47	9.00	122.67	1.15	122.83	5.30	122.84		
12.45	122.46	5.00	122.47	9.15	122.67	1.30	122.88	5.45	122.78	Total,	11,896.99
1.00	122.46	5.15	122.47	9.30	122.73	1.45	122.80	6.00	122.73		
1.15	122.46	5.30	122.47	9.45	122.74	2.00	122.88	6.15	122.86	Av.,	122.65

DISCHARGE HEAD. No. 2.

Time.	Difference.	Time.	Difference.	Time.	Difference.	Time.	Difference.	Time.	Difference.	Time.	Difference.
9.15	101.8	1.45	101.15	6.15	100.75	10.45	100.65	3.15	100.70	7.45	101.00
9.30	101.7	2.00	101.00	6.30	100.70	11.00	100.85	3.30	100.45	8.00	101.95
9.45	101.6	2.15	101.05	6.45	100.95	11.15	100.90	3.45	100.60	8.15	101.85
10.00	101.5	2.30	101.1	7.00	100.70	11.30	100.70	4.00	100.40	8.30	101.90
10.15	101.75	2.45	101.25	7.15	100.75	11.45	100.85	4.15	100.35	8.45	101.80
10.30	101.50	3.00	101.2	7.30	100.85	12.00	100.70	4.30	100.35	9.00	101.60
10.45	101.5	3.15	101.05	7.45	100.85	12.15	100.55	4.45	100.55	9.15	101.00
11.00	101.7	3.30	100.9	8.00	100.80	12.30	100.30	5.00	100.55		
11.15	101.5	3.45	101.2	8.15	100.90	12.45	100.75	5.15	100.15		
11.30	101.5	4.00	100.65	8.30	100.65	1.00	101.35	5.30	99.85	Total,	9,785.79
11.45	101.5	4.15	100.69	8.45	100.50	1.15	100.35	5.45	100.45		
12.00	101.35	4.30	101.05	9.00	100.75	1.30	100.80	6.00	100.60	Av.,	100.88
12.15	101.2	4.45	100.90	9.15	100.40	1.45	100.95	6.15	100.30		
12.30	101.5	5.00	100.65	9.30	100.35	2.00	100.20	6.30	100.40		Inches of mercury.
12.45	101.15	5.15	100.80	9.45	100.60	2.15	100.35	6.45	99.30		
1.00	101.15	5.30	101.05	10.00	100.40	2.30	100.45	7.00	100.15		
1.15	101.3	5.45	101.00	10.15	100.45	2.45	100.45	7.15	100.85		
1.30	101.2	6.00	100.80	10.30	100.60	3.00	100.65	7.30	101.05		

LEVEL IN CHAMBERS ABOVE MARK. No. 26.

Time.	Reading.	Time.	Reading.	Time.	Reading.	Time.	Reading.	Time.	Reading.	Time.	Reading.
9.15	145.1	1.30	145.7	5.45	146.0	10.00	146.3	2.15	146.1	6.30	146.4
9.30	145.1	1.45	145.7	6.00	146.0	10.15	146.3	2.30	146.1	6.45	146.3
9.45	145.1	2.00	145.8	6.15	146.0	10.30	146.2	2.45	146.1	7.00	145.6
10.00	145.2	2.15	145.8	6.30	146.0	10.45	146.2	3.00	146.2	7.15	144.9
10.15	145.2	2.30	145.8	6.45	146.1	11.00	146.2	3.15	146.2	7.30	144.5
10.30	145.2	2.45	145.9	7.00	146.1	11.15	146.3	3.30	146.2	7.45	144.5
10.45	145.3	3.00	145.9	7.15	146.1	11.30	146.3	3.45	146.2	8.00	144.5
11.00	145.3	3.15	145.9	7.30	146.2	11.45	146.3	4.00	146.2	8.15	144.6
11.15	145.3	3.30	146.0	7.45	146.2	12.00	146.3	4.15	146.3	8.30	144.6
11.30	145.4	3.45	146.0	8.00	146.2	12.15	146.3	4.30	146.3	8.45	144.6
11.45	145.4	4.00	146.1	8.15	146.2	12.30	146.4	4.45	146.3	9.00	144.6
12.00	145.5	4.15	146.1	8.30	146.3	12.45	146.4	5.00	146.3	9.15	144.6
12.15	145.5	4.30	146.2	8.45	146.3	1.00	146.5	5.15	146.3		
12.30	145.5	4.45	146.2	9.00	146.3	1.15	146.2	5.30	146.3		
12.45	145.5	5.00	146.1	9.15	146.3	1.30	146.0	5.45	146.4	Total,	14,149.2
1.00	145.6	5.15	146.0	9.30	146.3	1.45	146.1	6.00	146.4		
1.15	145.6	5.30	145.9	9.45	146.3	2.00	146.1	6.15	146.4	Av.,	145.87

TEMPERATURE CONDENSING WATER AND CONDENSED STEAM. No. 18.

Time.	Temperature hot condensing water. °F.	Temperature cold condensing water. °F.	Temperature condensed steam. °F.	Time.	Temperature hot condensing water. °F.	Temperature cold condensing water. °F.	Temperature condensed steam. °F.	Time.	Temperature hot condensing water. °F.	Temperature cold condensing water. °F.	Temperature condensed steam. °F.
9.15	85	53	91	5.30	85	52	89	1.30	84	52	89
9.30	85	52	91	5.45	85	52	89	1.45	85	52	89
9.45	85	52	90	6.00	85	52	89.5	2.00	85	52	89
10.00	85	51	89.5	6.15	85	52	89.5	2.15	86	52	89
10.15	85	51	89.0	6.30	85	52	89.5	2.30	86	52	89
10.30	85	52	89	6.45	85	52	89	2.45	86	52	89
10.45	85	51	89	7.00	85	52	89	3.00	86	52	89
11.00	85	52	89	7.15	85	52	89	3.15	86	52	89
11.15	85	52	89	7.30	85	52	89	3.30	86	52	89
11.30	85	51	89	7.45	85	52	89	3.45	86	52	89
11.45	85	52	89	8.00	85	52	89.5	4.00	85	52	89
12.00	85	52	89.5	8.15	85	52	89.5	4.15	85	52	89
12.15	85	52	89	8.30	85	52	89.5	4.30	86	52	89
12.30	85	52	89	8.45	85	52	89.5	4.45	86	52	89
12.45	85	52	89	9.00	85	52	89.5	5.00	85	52	89
1.00	85	52	89.5	9.15	84	52	89.5	5.15	85	52	89
1.15	85	51	89.5	9.30	85	52	89	5.30	86	52	89
1.30	85	52	89.5	9.45	85	52	89	5.45	86	52	89
1.45	85	52	89.5	10.00	85	52	89	6.00	86	52	89
2.00	85	52	89.5	10.15	85	52	89	6.15	86	52	89
2.15	84	52	89	10.30	85	52	89	6.30	86	52	89
2.30	85	52	89.5	10.45	85	52	89	6.45	86	52	89
2.45	85	52	89.5	11.00	85	52	89	7.00	86	52	89
3.00	85	52	89.5	11.15	85	52	89	7.15	86	52	89
3.15	85	52	89.5	11.30	85	52	89	7.30	86	52	89
3.30	85	52	89.5	11.45	85	52	89	7.45	86	52	89
3.45	84	51	89.5	12.00	85	52	89	8.00	86	52	89
4.00	85	52	90	12.15	85	52	89	8.15	86	52	91
4.15	85	52	89.5	12.30	85	52	89	8.30	86	52	91
4.30	85	52	89	12.45	85	52	89.5	8.45	86	52	91
4.45	85	52	89.5	1.00	85	52	89.5	9.00	86	52	91
5.00	85	52	89	1.15	84	52	89.5	9.15	86	52	91
5.15	85	52	89								

CCUNTER, PRESSURES, ETC. No. 3.

Time.	Revolutions.	Pressure in first receiver.	Pressure in second receiver.	Pressure at throttle.	Vacuum in condenser.	Pressure in L. P. jacket.	Time.	Revolutions.	Pressure in first receiver.	Pressure in second receiver.	Pressure at throttle.	Vacuum in condenser.	Pressure in L. P. jacket.
8.30	....	....	....	86	....	....	10.15	762	45.5	2.2	179	27.31	100
8.45	....	....	....	82	....	....	10.30	763	46	2.4	179	27.23	
9.00	....	....	....	98	....	....	10.45	761	46	2.2	175	27.29	
9.15	....	49	2.5	175	27.15	100	11.00	760	45.8	2.4	180	27.24	
9.30	733	48	2.5	180	27.20		11.15	761	46	2.2	179	27.31	100
9.45	757	48	2.5	180	27.20		11.30	762	46	2.5	180	27.22	
10.00	759	48	2.5	179	27.21		11.45	761	46	2.5	179	27.25	
10.15	758	48	2.4	177	27.24	100	12.00	761	45.5	2.3	174	27.26	
10.30	760	48	2.3	178	27.22		12.15	760	45.8	2.4	179	27.22	100
10.45	758	48	2	179	27.25		12.30	761	45	2.3	178	27.22	
11.00	759	48	2	179	27.22		12.45	760	46	2.5	178	27.20	
11.15	759	48	2.2	179	27.22	100	1.00	760	46	2.5	175	27.16	
11.30	761	48	2.2	178	27.25		1.15	760	45	2	178	27.21	100
11.45	760	48	2.2	179	27.22		1.30	760	46	2.5	178	27.21	
12.00	760	48	2.1	180	27.25		1.45	757	46	2.5	170	27.22	
12.15	760	48	2.2	179	27.25	100	2.00	763	48	2.3	179	27.21	
12.30	761	48	2.2	180	27.25		2.15	759	47	2.4	180	27.22	100
12.45	761	48	2.2	180	27.25		2.30	761	47	2.3	179	27.26	
1.00	763	48	2.2	180	27.26		2.45	761	47	2.3	179	27.25	
1.15	763	46	2.1	180	27.25	100	3.00	761	46	2.3	175	27.24	
1.30	758	45	2.3	180	27.25		3.15	761	45	2.3	179	27.22	100
1.45	760	46	2.5	179	27.23		3.30	761	46	2	178	27.23	
2.00	760	46	2.5	179	27.25		3.45	757	45	2.3	178	27.22	
2.15	759	46	2.5	180	27.23	100	4.00	757	47	2	178	27.22	
2.30	760	46	2.5	175	27.23		4.15	760	46	2	179	27.22	100
2.45	760	46	2.5	179	27.22		4.30	756	46	2	179	27.23	
3.00	760	46	2.5	179	27.25		4.45	758	46	2.5	179	27.21	
3.15	758	46	2.5	180	27.25	100	5.00	757	47	2.5	178	27.26	
3.30	760	46	2.5	179	27.22		5.15	757	45	2.5	176	27.22	100
3.45	758	46	2.5	180	27.22		5.30	745	50	3	140	27.22	
4.00	757	46	2.5	179	27.25		5.45	749	50	3	149	27.18	
4.15	757	45	2.5	179	27.22	100	6.00	760	47	2.5	170	27.22	
4.30	756	46	2.5	179	27.25		6.15	760	47	2	179	27.28	107
4.45	756	46	2.5	180	27.25		6.30	758	47	2.5	179	27.25	
5.00	760	46	2.5	179	27.25		6.45	759	45	2	178	27.25	
5.15	759	46	2.4	179	27.29	100	7.00	761	44	1.5	179	27.27	
5.30	760	46	2.5	175	27.37		7.15	759	44	1.5	178	27.22	97
5.45	760	46	2.5	179	27.30		7.30	759	47	2.5	178	27.20	
6.00	761	46	2.3	179	27.32		7.45	758	46	2.5	178	27.22	
6.15	760	45.5	2.3	178	27.29	100	8.00	758	46	2.5	174	27.21	
6.30	760	45	2.3	178	27.24		8.15	755	46	2.5	176	27.21	97
6.45	760	45.4	2.3	178	27.34		8.30	757	46	2.5	179	27.22	
7.00	760	45.5	2.3	180	27.30		8.45	757	46	2.5	178	27.22	
7.15	760	45.5	2.3	179	27.29	100	9.00	749	49	3	160	27.21	
7.30	758	46	2.4	179	27.31		9.15	735	55	4.5	110	27.09	90
7.45	760	46	2.4	179	27.36								
8.00	760	46	2.5	175	27.35		Total,	72,843					
8.15	760	45.3	2.5	178	27.31	100							
8.30	763	46	2.5	180	27.28		Totals,		4,506.6	230.5	17,143	2,642.71	2,491
8.45	763	46	2.5	180	27.31								
9.00	762	45.5	2.4	179	27.27		Av.,		46.46	2.38	176.73	27.25	99.6
9.15	763	45	2.3	180	27.24	100							
9.30	762	46	2.1	180	27.25								
9.45	762	45.5	2.3	179	27.31								
10.00	762	45.8	2.2	179	27.32								

Cor. av., $\frac{1}{175.7}$

Reading of counter at 9.09, 422,741.
Reading of counter at 9.26, 496,257.

WEIGHT AIR PUMP WATER. No. 5.

Barrel No. 1 full.	No. 1 empty.	Difference No. 1.	Time when emptied.	Barrel No. 2 full.	No. 2 empty.	Difference No. 2.	Time when emptied.	Barrel No. 1 full.	No. 1 empty.	Difference No. 1.	Time when emptied.	Barrel No. 2 full.	No. 2 empty.	Difference No. 2.	Time when emptied.
1,001	408	593	On starting engine.	620	227	393	....	989	421	568	10.55	1,280	237	1,043	11.25
1,245	1,001	244	9.15	536	270	266	....	1,175	420	755	11.12	863	239	624	12.00
864	454	410	....	591	257	334	....	1,288	416	872	11.35	864	242	622	12.10
910	504	406	....	995	264	731	....	1,200	476	724	11.50	1,275	238	1,037	12.20
1,143	496	647	....	879	267	612	....	1,383	420	963	12.07	1,131	239	892	12.30
1,279	450	829	....	1,182	280	902	10.30	1,502	429	1,073	12.25	1,140	244	896	12.44
1,609	520	1,089	10.20	1,372	242	1,130	11.00	1,098	430	688	12.35	1,312	242	1,070	1.00
1,700	443	1,257	10.50	1,290	253	1,037	11.25	1,483	416	1,067	12.55	1,097	246	851	1.25
1,822	502	1,320	11.15	1,353	240	1,113	11.55	1,379	429	950	1.14	1,153	258	895	1.45
1,832	463	1,369	11.40	1,360	240	1,120	12.20	1,645	454	1,191	1.36	871	270	601	2.07
1,869	438	1,431	12.10	1,391	254	1,137	12.55	1,120	480	640	1.58	795	251	514	2.21
1,840	421	1,419	12.40	1,380	248	1,132	1.15	1,154	479	675	2.14	1,175	253	922	2.35
1,923	443	1,480	1.05	1,330	239	1,091	1.55	1,264	472	792	2.29	1,097	240	857	2.55
1,886	432	1,454	1.40	1,391	260	1,131	2.10	1,677	470	1,207	2.44	1,085	240	844	2.30
1,900	454	1,446	2.05	1,383	256	1,027	2.40	1,195	454	741	3.08	790	250	540	3.36
1,934	483	1,451	2.30	1,364	241	1,123	3.10	1,118	474	644	3.26	1,050	243	807	3.50
1,900	493	1,407	2.55	1,364	256	1,108	3.35	1,107	470	637	3.42	1,145	253	892	4.05
1,822	445	1,377	3.25	1,353	260	1,093	4.00	1,329	462	867	3.56	1,357	250	1,107	4.26
1,810	475	1,335	3.50	1,391	258	1,133	4.30	1,594	431	1,163	4.17	1,359	265	1,094	4.51
1,905	447	1,458	4.20	1,045	262	783	4.55	1,650	461	1,189	4.39	1,073	240	833	5.19
1,610	454	1,156	4.45	1,160	240	920	5.15	1,659	426	1,233	5.07	1,338	241	1,097	5.42
1,790	695	1,095	5.05	1,146	245	901	5.25	1,584	435	1,149	5.34	924	240	684	6.07
1,340	945	395	5.30	866	248	618	5.50	1,183	434	749	5.56	1,100	243	857	6.21
1,186	465	721	5.45	1,086	244	842	6.10	1,556	429	1,127	6.15	920	245	675	6.44
1,344	487	857	6.00	1,167	236	931	6.30	973	448	525	6.34	1,128	254	874	6.56
1,220	473	747	6.20	1,258	233	1,025	6.50	1,236	443	793	6.49	989	258	731	7.16
1,476	417	1,059	6.40	1,042	238	804	7.15	1,425	449	976	7.06	951	250	701	7.37
1,488	429	1,059	7.05	1,241	130	1,111	7.35	1,282	480	802	7.29	907	245	662	7.55
1,490	413	1,077	7.25	1,144	243	901	7.55	1,404	477	927	7.47	1,069	252	817	8.11
1,249	431	818	7.40	1,185	248	937	8.15	1,217	457	760	8.04	1,011	251	760	8.29
1,300	418	882	8.05	1,208	239	969	8.40	1,274	444	830	8.21	1,343	249	1,094	8.48
1,538	416	1,122	8.30	1,110	240	870	9.00	1,295	446	849	8.40	635	276	359	9.10
1,433	418	1,015	8.50	1,107	237	870	9.20	1,077	456	621	8.57	1,480	After 9.15.	845	....
1,302	419	883	9.05	1,245	241	1,004	9.40	....							
1,275	418	857	9.30	832	237	595	9.55	....							
1,168	416	752	9.50	883	236	647	10.10	....	Total from 9.15 to 9.15, 128,471.						
1,156	468	688	10.02	1,053	247	806	10.30	....							
1,187	420	767	10.18	924	242	682	10.48	....	Total from 9.09 to 9.26, 129,909.						
1,470	423	1,047	10.40	1,070	237	833	11.30	....							

CALORIMETER.

Time.	Boiler pressure.	Back pressure.	Temperature.	Quality of steam.	Time in use.	Time.	Boiler pressure.	Back pressure.	Temperature.	Quality of steam.	Time in use.
10.30	Started.					3.06	175	15	155	....	
10.40	175	16	155			3.07	175	15	155	....	
10.41	175	16	155	.988	15 min.	3.08	Shut off.				
10.42	175	16	155	....		5.52	Started.				
10.43	176	16	154.5	....		6.04	175	15	155	....	
10.44	175	16	155	....		6.05	175	15	155	....	
10.45	Shut off.					6.06	175	15	155	....	17 min.
11.47	Started.					6.07	175	15	155	....	
12.02	174	15	155	....		6.08	175	15	155	....	
12.03	174	15	155	....	20 min.	6.09	Shut off.				
12.04	174	15	155	....		7.48	Started.				
12.05	174	15	154.8	....		8.05	175	15	155.1	....	
12.06	174	15	155	....		8.06	174	15	155.2	....	
12.07	Shut off.					8.07	173	15	155.2	....	22 min.
2.46	Started.					8.08	173	15	155.2	....	
3.03	175	15	155	....		8.09	174	15	155.2	....	
3.04	175	15	155	....		8.10	Shut off.				
3.05	175	15	155	....	22 min.						

Total time in use, 159 min.

EXTRA READINGS FOR STATION NO. 18.

Time.	Temperature hot well. °F.	Temperature suction barrel in boiler room. °C.	Time.	Temperature hot well. °F.	Temperature suction barrel in boiler room. °C.	Time.	Temperature hot well. °F.	Temperature suction barrel in boiler room. °C.
10.45	151		7.15	126	54	3.45	132	54
11.00	138	50	7.30	148	52	4.00	148	54
11.15	137	40	7.45	148	53	4.15	146	54
11.30	117	50	8.00	126	54	4.30	146	52
11.45	125	50	8.15	160	57	4.45	150	53
12.00	125	50	8.30	128	53	5.00	146	55
12.15	155	50	8.45	138	53	5.15	142	53
12.30	152	45	9.00	144	53	5.30	131	54
12.45	141	55	9.15	150	52	5.45	140	52
1.00	122	53	9.30	154	54	6.00	148	50
1.15	121	53	9.45	123	56	6.15	139	49
1.30	122	52	10.00	137	54	6.30	154	54
1.45	158	51	10.15	140	53	6.45	141	51
2.00	167	60	10.30	150	56	7.00	128	52
2.15	150	31	10.45	131	58	7.15	151	48
2.30	127	56	11.00	164	52	7.30	138	57
2.45	126	56	11.15	138	53	7.45	149	52
3.00	131	55	11.30	134	55	8.00	141	55
3.15	152	54	11.45	136	56	8.15	137	52
3.30	151	50	12.00	152	59	8.30	140	48
3.45	146	55	12.15	146	58	8.45	138	48
4.00	135	57	12.30	152	57	9.00	136	54
4.15	128	54	12.45	130	54	9.15	134	50
4.30	140	54	1.00	150	54			
4.45	139	53	1.15	141	54	Total,	12,713	3,759
5.00	136	52	1.30	145	54			
5.15	125	52	1.45	144	54			
5.30	133	54	2.00	126	54	Av.,	139.7°	41.3°
5.45	121	54	2.15	142	50			
6.00	150	53	2.30	126	53			
6.15	125	53	2 45	156	54			
6.30	153	54	3.00	144	54	Cor. av.,	$\frac{1}{140.7°}$	
6.45	136	55	3.15	130	54			
7.00	122	53	3.30	148	53			

JACKET TESTS. MAY 2.

Time.	Reading.	Difference.	Time.	Reading.	Difference.
Engine Stopped.			Engine Running.		
h. m. s.			h. m. s.		
1, 14, 0	0.45	...	11, 49, 11	0	3.0
1, 15, 10	1.00	.55	12, 2, 50	3.0 cu. ft.	1.0
1, 21, 0	1.73	.73	12, 6, 30	4.0	1.0
1, 24, 0	1.88	.15	12, 9, 4	5.0	3.2
1, 28, 0	2.13	.25	12, 19, 5	8.2	1.8
1, 34, 0	2.37	.24	12, 27, 17	10.0	Opened valve to blow out.
1, 39, 0	2.62	.25	12, 29, 0	.03	Valve closed.
1, 44, 0	2.83	.21	12, 34, 20	1.0	.97
1, 51, 0	3.12	.29	12, 38, 55	2.0	1.00
1, 54, 0	3.24	.12	12, 42, 28	3.0	1.00
		2.79	12, 47, 34	4.0	1.00
			12, 59, 49	8.0	4.00
			1, 4, 25	9.0	1.00
			1, 9, 30	9.45	0.45

.065 average for 1 min.
For 39 min., 8.30 to 9.09 = 2.5 cu. ft.
2.5 cu. ft. × 54.41 lbs. = 136 lbs.

Total, 78′-36″. Total, 19.42 cu. ft.
Av., .247 cu. ft. per min.
Jacket steam in 1,457 min. total engine time = 360 cu. ft.
Total, 360 cu. ft. at 54.41 lbs. = 19,587 lbs.

LOW JACKET TEST.

Engine Stopped.

Time.	Reading.	Difference.
11′, 20″	.20	
41′, 20″	1.03	.83
30 min.		

Engine Running.

54, 50		.20	
5, 40	35	1.00	.80
6, 15		.18	
24, 45		1.00	.82
25, 15	30	.14	
46, 15		1.04	.90
47, 30	75	.07	
8, 30		1.00	.93
9, 0	30	.14	
11, 20			
76, 30	170 secs.	.20	.06

73′-40″ = time running. 3.51 cu. ft.

STEAM IN SMALL ENGINE. No. 20.

Time steam turned in.	Weight of cold water.	Weight of hot water.	Time steam shut off.	Weight of steam.
8.32	1,144	1,176	10.00	32
10.07	1,026	1,068	11.37	42
11.45	1,063	1,107	1.15	44
1.21	1,115	1,161	3.01	46
3.07	1,092	1,138	4.31	46
4.37	1,040	1,090	6.12	50
6.18	1,043.5	1,092	7.48	48.5
7.54	1,054	1,117	9.54	63.0
10.01	1,091	1,142	11.31	51.0
11.37	1,079	1,130	1.07	51.0
1.14	1,095	1,136	2.44	41.0
2.51	1,137	1,180	4.21	43.0
4.28	1,155	1,206	5.58	51.0
6.07	1,064	1,114	7.37	50.0
7.45	1,021	1,063	9 25	42.0
				700.5

700.5 pounds in 23.3 hours.
722 pounds in 24 hours.

DRIPS.

Separator.				First Receiver.				Second Receiver.			
High level.	Low level.	Difference.	Time.	High level.	Low level.	Difference.	Time.	High level.	Low level.	Difference.	Time.
			h. m. s.				h. m. s.				h. m. s.
.60	.15	.45	9, 00	....	.19		9, 00	....	.27		9, 00
	.43		9, 15	....	.40	.21	9, 15	....	.35	.08	9, 15
1.05		.62	10, 29, 10	1.10		.70	9, 27½	1.02		.67	12, 22, 5
	.12		10, 29, 25		.17		9, 28¾		.23		12, 24, 30
1.01		.89	12, 26	1.10		.93	9, 55	1.00		.77	3, 51, 00
	.07		12, 26, 40		.19		9, 55, 47		.06		3, 51, 50
1.07		1.00	2, 22, 30	1.10		.91	10, 24, 50	1.13		1.07	7, 13, 30
	.08		2, 22, 50		.12		10, 25, 30		.10		7, 14, 25
1.15		1.07	4, 50, 15	1.10		.98	10, 56, 25	1.10		1.00	10, 41, 10
	.09		4, 51, 10		.16		10, 57, 10		.15		10, 42, 10
1.11		1.02	7, 17, 00	1.10		.95	11, 25	1.14		.99	1, 55, 00
	.15		7, 18, 00		.08		11, 25, 40		.05		1, 56, 30
1.10		.95	9, 40, 50	1.10		1.02	11, 54, 40	1.14		1.09	5, 04, 10
	.10		9, 41, 40		.13		11, 55, 25		.05		5, 05, 30
1.18		1.08	11, 58, 00	1.10		.97	12, 22, 45	1.10		1.05	7, 56, 40
	.10		11, 59, 00		.05		12, 23, 35		.19		7, 57, 45
1.18		1.08	2, 30, 12	1.16		1.11	12, 57, 30	.68		.49	9, 15
	.20		2, 30, 40		.05		12, 58, 40		.68		.....
1.18		.98	4, 42, 20	1.13		1.08	1, 29, 30	.80		.12	9, 26
	.09		4, 44, 20		.07		1, 30, 30				
1.09		1.00	7, 26, 00	1.11		1.04	1, 47, 22				
	.08		7, 27, 50		.06		1, 48, 10				
.63		.55	9, 15	1.12		1.06	2, 26, 43				
	.63				.08		2, 26, 30				
.63		0	9, 26	1.12		1.04	2, 45, 35				
					.10		2, 46, 15				
				1.10		1.00	3, 22, 30				
					.10		3, 23, 10				
				1.10		1.00	3, 49, 10				
					.05		3, 50, 00				
				1.11		1.06	4, 20, 45				
					.16		4, 21, 30				
				1.16		1.00	4, 48, 00				
					.11		4, 48, 45				
				1.12		1.01	5, 17, 00				
					.12		5, 17, 40				
				1.12		1.00	5, 45, 30				
					.12		5, 46, 15				

DRIPS. — *Continued.*

First Receiver.				First Receiver.				Low Jacket.			
High level.	Low level.	Difference.	Time.	High level.	Low level.	Difference.	Time.	High level.	Low level.	Difference.	Time.
			h. m. s.				h. m. s.				h. m. s.
1.13		1.01	6, 13, 00						.13		9, 00
	.12		6, 13, 40	.97		.91	2, 32, 10		.70	.57	9, 15
1.16		1.04	6, 40, 30		.09		2, 32, 50	1.10		.40	9, 23, 20
	.15		6, 41, 05	1.16		1.07	2, 59, 42		.02		9, 23, 55
1.14		.90	7, 07, 15		.05		3, 00, 15	1.10		1.08	9, 46, 55
	.06		7, 07, 45	1.13		1.08	3, 28, 00		.05		9, 47, 25
1.15		1.09	7, 38, 10		.06		3, 29, 30	1.10		1.05	10, 9, 35
	.12		7, 38, 45	1.14		1.08	3, 55, 40		.02		10, 10, 5
1.15		1.03	7, 05, 30		.08		3, 56, 45	1.10		1.08	10, 27, 45
	.11		7, 06, 10	1.15		1.07	4, 23, 05		.10		10, 28, 14
1.13		1.02	8, 33, 40		.05		4, 24, 00	1.10		1.00	10, 54, 10
	.20		8, 34, 15	1.14		1.09	4, 50, 40		.14		10, 54, 40
1.13		.93	8, 41, 10		.06		4, 51, 40	1.10		.96	11, 14, 45
	.10		8, 41, 50	1.15		1.09	5, 18, 10		.14		11, 15, 16
1.16		1.06	8, 58, 30		.08		5, 19, 10	1.12		.98	11, 26
	.08		8, 59, 10	1.15		1.07	5, 51, 10		.12		11, 26, 56
1.14		1 06	9, 27, 05		.07		5, 52, 08	1.12		1.00	11, 57, 40
	.11		9, 27, 45	1.14		1.07	6, 14, 35		.15		11, 58, 20
1.16		1.05	9, 55, 30		.09		6, 16, 00	1.10		.95	12, 18, 10
	.11		9, 56, 25	1.12		1.03	6, 39, 35		.15		12, 18, 40
1.16		1.05	10, 25, 20		.07		6, 40, 40	1.12		.97	12, 20, 17
	.10		10, 26, 0	1.14		1.07	7, 07, 30		.11		12, 20, 47
1.16		1.06	10, 55, 50		.06		7, 08, 30	1.11		1.00	1, 1, 40
	.13		10, 56, 50	1.14		1.08	7, 34, 05		.11		1, 2, 10
1.14		1.01	11, 25, 00		.06		7, 35, 14	1.11		1.00	1, 23
	.08		11, 25, 40	1.14		1.08	8, 00, 30		.09		1, 23, 32
1.13		1.05	11, 52, 30		.07		8, 01, 21	1.10		1.01	1, 44, 45
	.09		11, 53, 20	1.16		1.11	8, 27, 25		.06		1, 45, 15
1.13		1.04	12, 20, 00		.05		8, 28, 30	1.15		1.09	2, 8, 50
	.07		12, 20, 50	1.08		1.03	8, 52, 22		.07		2, 9, 17
1.16		1.09	12, 49, 05		.04		8, 53, 15	1.11		1.04	2, 31, 3
	.10		12, 49, 50	.51		.47	9, 06, 10		.08		2, 31, 30
1.13		1.03	1, 17, 00		.07		9, 06, 34	1.10		1.02	2, 52, 30
	.15		1, 17, 50	.35		.28	9, 15		.07		2, 54, 10
1.14		.99	1, 42, 48		.35		.. ..	1.12		1.05	3, 15, 30
	.07		1, 43, 40	.40		.05	9, 26		.09		3, 16, 0
1.14		1.07	2, 09, 03					1.10		1.01	3, 37, 5
	.08		2, 09, 50						.09		3, 37, 35

DRIPS. — *Concluded.*

Low Jacket.				Low Jacket.				Low Jacket.			
High level.	Low level.	Difference.	Time.	High level.	Low level.	Difference.	Time.	High level.	Low level.	Difference.	Time.
			h. m. s.				h. m. s.				h. m. s.
1.12		1.03	3, 59, 15	1.14		1.06	11, 55, 35	1.14		1.09	8, 04, 05
	.02		3, 59, 45		.08		11, 56, 25		.05		8, 04, 52
1.16		1.14	4, 25, 00	1.12		1.04	12, 18, 05	1.14		1.09	8, 29, 20
	.10		4, 26, 15		.08		12, 18, 45		.06		8, 30, 10
1.18		1.08	4, 50, 00	1.12		1.04	12, 40, 30	1.12		1.06	8, 54, 00
	.09		4, 50, 35		.10		12, 41, 10		.10		8, 54, 50
1.12		1.03	5, 12, 10	1.12		1.02	1, 02, 10	.64		.34	9, 07, 40
	.03		5, 12, 50		.10		1, 02, 40		.07		9, 08, 08
1.12		1.09	5, 36, 5	1.12		1.02	1, 44, 40	.41		.34	9, 15
	.03		5, 36, 50		.09		1, 25, 40		.41		....
1.17		1.14	6, 01, 20	1.13		1.04	1, 48, 10	1.06		.65	9,26
	.08		6, 02, 00		.07		1, 49, 15				
1.12		1.04	6, 24, 05	1.14		1.07	2, 11, 29				
	.07		6, 24, 35		.06		2, 12, 05				
1.13		1.06	6, 47, 00	1.09		1.03	2, 33, 38				
	.13		6, 47, 35		.06		2, 34, 24				
1.15		1.02	7, 10, 00	1.14		1.08	2, 58, 23				
	.10		7, 10, 30		.05		2, 59, 10				
1.14		1.04	7, 33, 15	1.14		1.09	3, 23, 10				
	.08		7, 33, 55		.06		3, 23, 56				
1.12		1.04	7, 56, 20	1.14		1.08	3, 47, 00				
	.10		7, 57, 00		.05		3, 47, 38				
1.12		1.02	8, 13, 55	1.14		1.09	4, 11, 46				
	.09		8, 14, 05		.05		4, 12, 20				
1.14		1.05	9, 04, 30	1.14		1.09	4, 36, 35				
	.05		9, 05, 00		.07		4, 37, 20				
1.17		1.12	9, 29, 35	1.14		1.07	5, 01, 05				
	.05		9, 30, 20		.04		5, 02, 00				
1.12		1.07	9, 53, 40	1.14		1.10	5, 26, 15				
	.08		9, 54, 50		.06		5, 27, 23				
1.18		1.10	10, 23, 20	1.18		1.12	5, 53, 00				
	.08		10, 24, 20		.05		5, 53, 56				
1.12		1.04	10, 46, 00	1.14		1.09	6, 14, 50				
	.04		10, 46, 50		.07		6, 15, 30				
1.12		1.08	10, 09, 40	1.14		1.07	6, 43, 40				
	.10		10, 10, 15		.05		6, 44, 35				
1.12		1.02	11, 31, 45	1.14		1.09	7, 09, 40				
	.08		11, 35, 25		.04		7, 10, 42				
				1.14		1.10	7, 36, 52				
					.05		7, 38, 15				

WOOD FIRED, ASHES, ETC. No. 20.

Time.	Weight of barrow and coal.	Weight of barrow and coal, if any.	Weight of coal fired.	Weight of full barrows.	Time of full barrows.	Time.	Weight of barrow and coal.	Weight of barrow and coal, if any.	Weight of coal fired.	Weight of full barrows.	Time of full barrows.
8.30	401.5[1]										
8.30	1,717			1,717	8.30	4.30	1,575			1,575	4.30
9.00		692	1,025			5.00		1,429	146		
9.00	1,744			1,744	9.00		1,429				
9.30		1,255	489			5.30		992	437		
9.30	1,255					6.00	992				
10.00		1,196	59			6.00		692	300		
10.00	1,196					6.00	1,575			1,575	6.00
10.30		1,072	124			6.30		1,297	278		
10.30	1,072						1,297				
11.00		845	227			7.00		994	303		
11.00	845						994				
11.30		692	153	1,566	11.30	7.30		692	302		
11.30	1,566					7.30	1,674			1,674	7.30
12.00		1,212	354			8.00		1,304	370		
12.00	1,212						1,304				
12.30		692	520	1,698	12.30	8.30		955	349		
12.30	1,698					8.45	955				
1.00		1,473	225			8.45		692	263		
1.00	1,473					8.45	1,633			1,633	8.45
1.30		1,111	362			9.00		1,538	95		
1.30	1,111						1,538				
2.00		692	419	1,543	2.00	9.30		1,155	383		
2.00	1,543						1,155				
2.30		1,173	370			10.00		841	314		
2.30	1,173					10.00	1,653			1,653	10.00
3.00		908	265			10.30		1,277	376		
3.00	908						1,277				
3.15		692	216			11.00		946	331		
3.15	1,659			1,659	3.00		946				
3.30		1,450	209			11.15		692	254		
3.30	1,450					11.27	1,688			1,688	11.27
4.00		1,085	365			11.30		1,638	50		
4.00	1,085						1,638				
4.30		692	393			12.00		1,312	326		
						12.30	1,312				
								1,015	297		
						1.00	1,015				
								692	323		

[1] 401.5 = pounds of wood.

WOOD FIRED, ASHES, ETC. No. 20. — *Continued.*

Time.	Weight of barrow and coal.	Weight of barrow and coal, if any.	Weight of coal fired.	Weight of full barrows.	Time of full barrows.	Time.	Weight of barrows and coal.	Weight of barrows and coal, if any.	Weight of coal fired.
1.30	1,442	1,018	424	1,442	1.03	8.30	1,259	962	297
2.00	1,018	692	326			9.00	962	774	188
2.05	1,566			1,566	2.05				
2.30	1,090	1,090	476						
3.00	865	865	225						
3.12	1,714	692	173						
3.30	1,576	1,576	138	1,714	3.15				
4.00	1,165	1,165	411						
4.30	842	842	323						
4.47	1,662	692	150	1,662	4.47				
5.00	1,417	1,417	245						
5.30	1,037	1,037	380						
5.45	823	823	214						
5.49	1,587	692	131	1,587	5.50				
6.00	1,387	1,387	200						
6.30	1,164	1,164	223						
7.00	903	903	261						
7.19	1,725	692	211	1,725	7.23				
7.30	1,536	1,636	89						
8.00		1,259	377						

Total, 16,734 + 161 = 16,895 pounds fired, including wood.

Coal and Ashes (from grate).

Weight of barrow No. 1, and refuse.	Weight of barrow No. 1, empty.	Difference.	Weight of barrow No. 2, and refuse.	Weight of barrow No. 2, empty.	Difference.
248	138	110	203.5	89	114.5

From under the grate.

Weight of barrow No. 1, full.	Weight of barrow No. 1, empty.	Difference.	Weight of barrow No. 2, full.	Weight of barrow No. 2, empty.	Difference.
300	138	162.0	233	89	144.0
285	138	147.0	238.5	89	149.5
285	138	147.0	252.5	89	163.5
288.5	138	150.5	....	...	....

Total weight from grate 224.5 pounds, $\frac{1}{4}$ of 224.5 considered good coal = 56.0 pounds.
Total weight from ash-pit 1,063.5 pounds, $\frac{1}{17}$ of 1,063.5 good coal = 63 pounds.

BAROMETER TEMPERATURES. No. 24.

Time.	Barometer.	Temperature of room. °C.	Temperature of outside air. °C.	Time.	Barometer.	Temperature of boiler room. °C.	Temperature of outside air. °C.	Time.	Barometer.	Temperature of boiler room. °C.	Temperature of outside air. °C.
		No. 62,354 Cor.	No. 61,501 Cor.								
		0°–0.2	0°–0.1	6.15	30.29	24.9	6.0	4.15			—0.2
		100°–0.3	100°–0.0	6.30	30.29	25.3	6.0	4.30	30.23	21.0	—0.1
9.00		22.1		6.45			5.9	4.45		21.5	—0.4
9.15		25.0	8.7	7.00		26.0	5.8	5.00	30.23		—0.1
9.30		25.0	9.2	7.15		26.2	5.6	5.15			—0.2
9.45		26.5	8.9	7.30		26.1	5.6	5.30		21.6	0.0
10.00		26.8	9.0	7.45	30.29		5.0	5.45	30.23	20.1	0.2
10.15		26.8	9.3	8.00		24.8	4.2	6.00	30.24		1.0
10.30		27.0	9.8	8.15	30.29	24.4	4.1	6.15			1.5
10.45		26.8	9.8	8.30			3.8	6.30		21.9	2.5
11.00		27.3	10.3	8.45	30.29	25.2	3.0	6.45	30.25	23.0	3.1
11.15	30.27	27.2	10.5	9.00	30.29	25.6	2.6	7.00			3.9
11.30		26.8	10.1	9.15			2.4	7.15			4.8
11.45		26.8	10.0	9.30		25.3	2.4	7.30		24.0	5.1
12.00		26.8	10.0	9.45		25.3	2.0	7.45	30.25	24.0	5.3
12.15		27.0	9.6	10.00			2.6	8.00			6.9
12.30		27.1	9.4	10.15	30.27		2.2	8.15			6.9
12.45			9.0	10.30		24.5	1.8	8.30		25.0	7.5
1.00	30.30		9.7	10.45		24.5	2.0	8.45	30.23	25.0	8.0
1.15		25.2	9.7	11.00	30.26		1.5	9.00			8.1
1.30			8.7	11.15			1.2	9.15			8.9
1.45			8.5	11.30		24.6	0.8				
2.00			8.1	11.45		24.3	0.8				
2.15			9.0	12.00	30.25		1.5	Total,	907.61	1,381.7	405.6
2.30		26.8	8.1	12.15	30.25		1.0				
2.45	30.30		8.2	12.30		24.1	1.2	Av.,	30.25	24.7	4.2
3.00			8.1	12.45	30.25	23.5	0.7				
3.15			8.2	1.00			0.5				
3.30		25.6	7.8	1.15			0.8				
3.45	30.29	26.0	7.5	1.30	30.25	23.4	0.7				
4.00			7.5	1.45		23.9	0.2				
4.15		25.5	7.4	2.00	30.24		0.2				
4.30		25.5	7.1	2.15			0.0				
4.45	30.29			2.30		24.0	0.1				
5.00	30.29		7.0	2.45	30.24	23.5	0.0				
5.15		25.2	6.8	3.00			0.0				
5.30		25.5	6.8	3.15			—0.2				
5.45			6.7	3.30	30.23	23.0	—0.5				
6.00			6.5	3.45		21.9	—0.3				
				4.00	30.23		—0.8				

BOILER WATER AND MAKE-UP. No. 19.

Barrel No. 1 full.	No. 1 empty.	Difference No. 1.	Time when emptied.	Barrel No. 2 full.	No. 2 empty.	Difference No. 2.	Time when emptied.
875	421	454	Engine test began.				
1,146	875	271	9.15	815	390	425	9.15
935	430	505	....	1,353	370	983	9.30
1,310	432	878	....	718	388	330	9.45
1,305	427	878	10.15	1,247	375	872	10.00
1,311	425	886	10.45	1,404	418	986	10.30
1,351	411	940	11.00	1,515	386	1,129	10.50
1,205	405	800	11.15	1,450	387	1,063	11.10
1,510	409	1,101	11.40	1,313	372	941	11.25
1,510	416	1,094	12.05	1,533	390	1,143	11.45
1,470	419	1,051	12.30	1,523	383	1,140	12.15
1,047	427	620	12.40	821	380	441	12.35
1,321	432	889	12.50	1,219	384	835	12.45
1,512	429	1,083	1.10	1,560	360	1,200	12.55
1,485	720	765	1.45	1,526	718	808	1.30
1,500	417	1,083	2.00	1,551	381	1,170	1.50
1,090	432	658	2.10	853	390	463	2.05
1,440	422	1,018	2.20	942	367	575	2.15
1,512	738	774	2.35	1,538	371	1,167	2.30
1,565	432	1,133	3.05	1,542	1,209	333	2.55
1,512	417	1,095	3.25	1,653	374	1,279	3.10
....	....	....	....	1,516	377	1,139	3.30
1,512	421	1,091	3.40	1,548	370	1,178	3.55
1,422	415	1,007	4.10	1,520	373	1,147	4.25
1,565	408	1,157	4.30	1,563	362	1,201	4.40
1,505	410	1,095	4.45	1,550	780	770	4.50
1,507	471	1,036	5.10	1,633	393	1,240	5.20
1,537	426	1,111	5.30	1,628	396	1,232	5.35
1,531	430	1,101	5.45	1,573	392	1,181	6.00
1,530	479	1,051	6.20	1,636	383	1,253	6.30
1,416	413	1,003	6.35	1,184	392	792	6.40
1,132	417	715	6.45	1,515	384	1,131	7.00
1,534	827	707	7.15	1,694	1,295	399	7.20
1,480	1,410	70	7.22	1,705	1,540	165	7.25
1,570	475	1,095	7.30	1,635	565	1,070	7.35
1,500	729	771	7.50	1,632	363	1,269	8.00
1,507	463	1,044	8.05	1,177	385	792	8.15
1,035	432	603	8.20	890	397	493	8.25
1,145	424	721	8.30	1,556	392	1,164	8.40

BOILER WATER AND MAKE-UP. No. 19. — *Continued.*

Barrel No. 1 full.	No. 1 empty.	Difference No. 1.	Time when emptied.	Barrel No. 2 full.	No. 2 empty.	Difference No. 2.	Time when emptied.
1,534	436	1,098	8.55	1,624	376	1,248	9.10
1,513	416	1,097	9.15	1,003	388	615	9.20
1,010	421	589	9.25	1,007	383	624	9.30
1,077	420	657	9.40	1,650	662	988	9.50
1,534	800	734	10.00	1,618	385	1,233	10.10
1,547	413	1,134	10.15	1,019	372	647	10.20
763	408	355	10.30	520	372	148	10.35
560	400	160	10.38	1,030	369	661	10.40
1,473	455	1,018	10.45	1,590	382	1,208	11.00
1,322	413	909	11.15	1,578	397	1,181	11.25
1,541	420	1,121	11.40	1,652	366	1,286	11.55
1,543	414	1,129	12.00	1,504	386	1,118	12.05
1,103	403	700	12.15	1,092	364	728	12.20
1,118	415	703	12.25	1,209	390	819	12.35
1,243	411	832	12.45	1,065	368	697	12.50
1,368	408	960	1.04	1,138	361	777	1.12
1,017	407	610	1.21	1,330	369	961	1.30
1,242	409	833	1.38	1,080	368	712	1.45
955	417	538	1.50	776	369	407	1.53
807	407	400	1.57	905	363	542	2.00
1,086	411	675	2.03	1,107	362	745	2.08
868	405	463	....	966	364	602	2.20
1,088	416	672	2.26	1,083	362	721	2.34
970	412	558	2.42	740	452	288	2.50
918	412	506	2.53	783	372	411	3.00
812	404	408	3.02	1,200	345	855	3.08
1,158	405	753	3.15	1,145	362	783	3.22
1,080	412	668	3.30	1,047	356	691	3.39
1,079	412	667	3.45	1,084	359	725	3.50
815	405	410	3.56	776	348	428	4.02
857	407	450	4.05	811	359	452	4.12
856	414	442	4.20	1,060	361	699	4.25
1,139	407	732	4.30	1,000	350	650	4.36
1,047	403	644	4.45	1,008	363	645	4.50
1,017	410	607	4.56	961	357	604	5.04
975	410	565	5.10	932	355	577	5.15
953	410	543	5.22	940	352	588	5.27
1,461	401	1,060	5.37	1,195	346	849	5.42
978	402	576	5.47	751	355	396	5.53
650	411	239	5.54	952	351	601	5.58

BOILER WATER AND MAKE-UP. No. 19. — *Concluded.*

Barrel No. 1 full.	No. 1 empty.	Difference No. 1.	Time when emptied.	Barrel No. 2 full.	No. 2 empty.	Difference No. 2.	Time when emptied.
1,005	404	601	6.02	988	347	641	6.10
785	421	364	6.15	585	341	244	6.18
530	408	122	6.19	555	342	213	6.20
687	405	282	6.25	698	367	331	6.27
617	407	210	6.29	680	350	330	6.31
850	411	439	....	1,390	570	820	6.45
1,470	404	1,066	7.06	1,290	345	945	7.10
1,152	411	741	7.17	960	345	615	7.23
1,250	409	841	7.30	1,366	346	1,020	7.45
1,295	438	857	7.50	1,216	350	866	7.58
1,085	412	673	8.03	1,235	345	890	8.12
1,301	409	892	8.20	1,346	355	991	8.35
1,121	411	710	8.50	1,510	817	693	9.10
1,558	1,230	328	9.15	1,462	700	762	9.25
1,230	567	663	9.25				

Water weighed for boiler for entire test on boiler, including make-up = 151,060 lbs.
Leakage of feed pump = 1,440.
Total water fed, 149,620 lbs.

Make-up barrel full.	Empty.	Difference.	Time when emptied.
495	111	384	8.30
457	127	330	to
406	123	283	9.15
460	121	339	9.15
491	117	374	9.30
472	117	355	....
488	106	382	9.45
469	120	349	....
487	116	371	10.00
479	117	362	10.15
505	116	389	10.30
510	116	394	11.15
478	114	364	12.40
483	112	371	12.45
498	115	383	2.10
488	110	378	2.20
507	110	397	3.05
519	112	407	4.22
509	110	399	5.50
507	107	400	6.03
506	107	399	8.25
511	104	407	8.50
510	195	315	9.00

7,535 = make-up during 24 hours engine test.
997 = make-up before engine started.

8,532 = total make-up 24.93 hours.

TEMPERATURE OF FEED AND GASES BEFORE ENTERING AND AFTER LEAVING ECONOMIZER.

DRAUGHT. Nos. 21 AND 19.

Time.	Temperature of feed before. °F.	Temperature of feed after. °F.	Temperature of gases before. °F.	Temperature of gases after. °F.	Draught in inches of water.
9.00	170.8	179.8	322	206	....
9.15	128	184	378	214	....
9.30	99	189.5	404	223	....
9.45	108.5	194.4	404	215	....
10.00	96	194.8	398	208	....
10.15	111.5	194.8	399	203	....
10.30	101.8	191	402	198	....
10.45	115.4	182	405	196	....
11.00	132.8	171.1	403	195	.500
11.15	128	165	416	198	.060
11.30	112	162	422	203	.358
11.45	120.1	164.1	425	208	.098
12.00	133.7	170.1	428	212	.352
12.15	126.0	176	430	214	.236
12.30	129.8	179.8	434	215	.300
12.45	114	180	438	217	.268
1.00	128.1	176.5	436	212	.208
1.15	125.6	174.4	426	208	.296
1.30	123.2	176.3	424	204	.270
1.45	122	180.2	421	201	.322
2.00	128.3	182.0	422	202	.266
2.15	124.2	183.6	440	204	.060
2.30	129.7	182.0	437	198	.110
2.45	133.6	182.3	434	195	.322
3.00	129.1	184	430	190	.308
3.15	124.0	183.5	431	190	.408
3.30	130.1	184.2	437	192	.380
3.45	137.0	184.1	435	191	.352
4.00	136.0	183.9	434	191	.360
4.15	123.2	184.0	435	191	.346
4.30	126.7	184.5	430	189	.402
4.45	128.0	185.0	430	193	....
5.00	128.0	184.0	445	192.5	.246
5.15	127.0	185.0	440	194	.390
5.30	126.0	186.0	440	194	.090
5.45	132.2	184.0	446	196	.126
6.00	130.2	184.0	447	196	.090
6.15	126.0	185.0	425	195	.446
6.30	122.0	186.0	452	198	.064
6.45	133.0	187.0	460	200	.442
7.00	124.0	189.0	464	203	.400
7.15	130.0	192.0	466	210	.414
7.30	126.0	192.4	473	213	.454
7.45	120.0	197.5	475	219	.370
8.00	128.5	200.4	494	231	.410
8.15	125.0	204.0	496	240.5	.374
8.30	140 0	206.0	502	243	.130
8.45	123.5	206.0	493	236	.364
9.00	125.5	206.0	490	235	.148
9.15	125 4	207.5	497	237.5	.504
9.30	132.4	206.5	504	243	.090
9.45	137.0	207.0	507	243	.398
10.00	132.0	208.5	494	241	.434
10.15	125.0	208.3	508	245	.490
10.30	128.5	207.4	519	252	.170
10.45	136.0	207.5	518	252	.406
11.00	132.5	207.5	516	255.5	.458
11.15	128.0	210.0	519	256.0	.238
11.30	128.0	211.7	518	254.0	.174
11.45	128 3	217.5	520	257.0	.536
12.00	127.0	218.0	524	256.5	.130
12.15	137.0	217.5	526	256.0	.534
12.30	134.0	212.0	520	255.0	.541
12.45	132.0	211.0	530	258.0	.578
1.00	126.0	212.0	532	258.0	.598
1.15	126.0	213.0	530	253.0	.500
1.30	130.0	214.0	516	245.0	.636
1.45	132.0	217.0	518	246.0	.576
2.00	134.0	212.0	526	250.0	.580
2.15	128.0	212.0	534	254.0	.460
2.30	126.0	210.0	530	251.0	.208
2.45	124.0	208.0	530	244.0	.560
3.00	135.0	208.0	510	246.0	.478
3.15	124.0	207.0	516	236.0	.510
3.30	125.0	207.0	524	254.0	.502
3.45	128.0	207.0	530	258.0	.496
4.00	124	207	536	264	.530
4.15	132	207	542	264	.540
4.30	122	209	554	203	.526
4.45	132	212	550	268	.534
5.00	134	212	556	266	.284
5.15	134	214	554	264	.518
5.30	132	212	510	268	.508
5 45	127	210	520	268	.584
6.00	108	210	550	272	.408
6.15	116	210	554	272	.558
6.30	117	210	558	270	.414
6.45	136	212	546	267	.416
7.00	135	216	540	264	.558
7.15	123	213	544	265	.560
7.30	128	216	552	267	.604
7.45	132	216	554	270	.524
8.00	134	216	560	268	.516
8.15	134	216	552	268	.528
8.30	117	213	558	266	.522
8.45	118	214	560	264	.412
9.00	110	215	552	262	.408
9.15	111	212	522	246	.234
9.30	121	210	490	228	.190
Total,	12,521.7	19,630.1	47,848	22,842.5	34.195
Av.,	126.5	198.3	483	231	.375
			19.0	2	
Cor. av.,	127.0	198.3	502.0	233.0	

WEIGHT OF COAL, BOILER PRESSURE, ETC. No. 20.

Time.	Boiler pressure. (Lbs.)	Temperature of returns at boiler. °F.	Time.	Boiler pressure. (Lbs.)	Temperature of returns at boiler. °F.	Time.	Boiler pressure. (Lbs.)	Temperature of returns at boiler. °F.
8.30	91	322	6.00	184	373	3.30	184	373
8.45	86	321	6.15	184	373	3.45	185	373
9.00	99	329	6.30	183	373	4.00	183	373
9.15	173	366	6.45	183	373	4.15	184	373
9.30	184	374	7 00	185	373	4.30	183	373
9.45	185	374	7.15	185	373	4.45	184	373
10.00	185	374	7.30	184	373	5.00	185	373
10.15	185	374	7.45	184	373	5.15	181	373
10.30	185	374	8.00	185	373	5.30	145	355
10.45	185	374	8.15	184	373	5.45	160	360
11.00	185	374	8.30	185	373	6.00	183	373
11.15	185	374	8.45	185	373	6.15	185	373
11.30	185	374	9.00	185	373	6.30	185	373
11.45	185	374	9.15	185	373	6.45	185	373
12.00	185	374	9.30	185	373	7.00	184	373
12.15	185	374	9.45	185	373	7.15	183	373
12.30	185	374	10.00	185	373	7.30	184	373
12.45	185	374	10.15	185	373	7.45	185	373
1.00	185	374	10.30	184	373	8.00	185	373
1.15	185	374	10.45	185	373	8.15	181	373
1.30	185	374	11.00	185	373	8.30	185	373
1.45	185	374	11.15	185	373	8.45	182	373
2.00	185	374	11.30	185	373	9.00	163	365
2.15	184	374	11.45	185	373	9.15	117	343
2.30	184	374	12.00	184	373	9.25	93	325
2.45	185	374	12.15	184	373			
3.00	184	374	12.30	183	373			
3.15	184	374	12.45	184	373	Total,	18,073	37,432
3.30	184	374	1.00	180	373			
3.45	185	374	1.15	185	373			
4.00	184	374	1.30	184	373	Av.,	178.9	370.6
4.15	184	374	1.45	175	373			
4.30	185	374	2.00	183	373	Cor. av.,		369.6
4.45	184	374	2.15	184	373			
5.00	185	373	2.30	185	373			
5.15	183	373	2.45	185	373			
5.30	184	373	3.00	184	373			
5.45	183	373	3.15	184	373			

FLUE GASES. NOS. 22 AND 23.

Time.	CO_2.	O.	CO.	Time.	CO_2.	O.	CO.
10.35	12.7	5.1	0	9.00	11.0	9.0	0
	12.6	5.2	0	9.15	10.2	11.0	0
11.05	11.5	7.9	0	9.30	14.6	2.8	0
11.15	15.1	3.4	0	9.45	8.2	1.1	0 6
11.30	11.8	5.8	0	10.00	14.6	1.8	0.2
11.45	13.2	5.6	0	10.15	9.8	10.2	0
12.00	10.6	4 4	0	10.30	10.4	9.4	0
12.15	13.0	5.0	0	10.45	7.5	12.7	0.2
12.30	13 6	1.4	1.4	11.00	10.2	9 6	0
12.45	12.6	2.8	0.2	11.15	9.2	9.2	0.4
1.00	7.6	12.4	0	11.30	7.4	13.6	0
1.15	10.4	4.8	0.4	11.45	10.8	8.6	0
1.30	14	5.2	0	12.00	10.0	9.8	0
1.45	—	—	—	12.15	8.8	10.4	0
2.00	12.8	5.2	0	12.30	9.2	9.5	0
2.15	13.9	3.7	0	12.45	9.5	1.7	0
2.30	13.3	1.5	0.2	1.00	14.6	2.9	0
2.45	12.5	4.1	0	1.15	9.7	3.5	0
3.00	13.2	5.1	0	1.30	8.7	7.9	0.3
3.15	11.1	7.3	0	1.45	2.0	8.0	0
3.30	13.3	1.3	0.8	2.00	3.5	13.5	0.2
3.45	—	—	—	2.15	5.0	13.0	0
4.00	12.4	2.7	0.2	2.30	15.0	5.0	0
4.15	14.8	3.9	0	2.45	6.5	9.5	0
4.30	13.3	1.9	0.2	3.00	12.0	6.0	0.4
4.45	13.1	2.3	0.4	3.15	5.0	12.5	0
5.00	6.2	13.1	0.7	3.30	6.5	9.6	0
5.15	11.9	7.9	0	3.45	3.5	10 0	0
5.30	15.2	2 8	0.2	4.00	9.0	10.0	0.7
5.45	15.2	2.4	0	4.15	3.5	8.5	0
6.00	15.7	2.1	0	4.30	2.5	8.2	0.1
6.15	14.8	1.1	0	4.45	2.8	7.9	0.2
6.30	10.4	9.4	0.9	5.00	2.5	6.0	0
6.45	—	—	—	5.30	2.5	10.5	0
7.00	10.0	9.4	0	6.00	8.0	10.2	0
7.15	9.9	6.7	0.8	6.30	4.5	11.5	0.1
7.30				7.00	2 0	12.3	0
7.45	6.6	12.2	0	7.30	3.5	12.0	0.5
8.00	9.6	10.4	0	8.00	4.0	11.8	0.5
8.15	8.6	11.4	0	8.30	8.0	11.0	0
8.30	15.2	3.8	0	9.00	3.0	12.0	0
8.45	15.0	1.6	0.8				

WEIR READINGS.

Time.	Hook gauge. No. 7.	Hook gauge. No. 6.	Water collected. No. 5.	Time.	Temperature.	Water column. No. 1.[1]
9.15–10	1.0348	1.0355	248.03	10.30	52.0	10.068
10–11	1.0347	1.0351	248.03	11.00	52.0	10.058
11–12	1.0351	1.0354	248.03	11.30	52.3	10.063
12–1	1.0356	1.0356	248.03	12.00	52.2	10.066
1–2	1.0359	1.0356	248.03	12.30	52.0	10.066
2–3	1.0353	1.0346	248 03	1.00	52.0	10.068
3–4	1.0338	1.0333	248 03	1.30	52.0	10.038
4–5	1.0325	1.0318	248.03	2.00	52.4	10.024
5–6	1.0291	1.0293	248.03	2.30	52.5	10.040
6–7	1.0329	1.0328	248 036	3.00	52.3	10.048
7–8	1.0327	1.0325	248.035	3.30	52.4	10.064
8–9	1.0353	1.0354	248.037	4.00	52.5	10.040
9–10	1.0309	1.0315	248.033	4.30	52.5	10.041
10–11	1.0322	1.0326	248.035	5.00	52.5	10.037
11–12	1.0316	1.0321	248.034	5.30	52.8	10.052
12–1	1.0346	1.0346	248.036	6.00	52.6	9.997
1–2	1.0271	1.0263	248.023	6.30	52.7	10.034
2–3	1.0326	1.0324	248.028	7.00	52.7	10.011
3–4	1.0296	1.0297	248.026	7.30	52.7	10.002
4–5	1.0298	1.0296	248.025	8.00	52.7	9.967
5–6	1.0226	1.0227	248.017	8.30	52.6	9.972
6–7	1.0202	1 0205	248.014	9.00	52.7	9.953
7–8	1.0227	1.0222	248.016	9.30	52.9	10.015
8–9	1.0289	1.0290	248 024	10.00	52.8	
9–9.15	1.0113	1.0089	248.008	10.30	52.8	
				11.00	52.8	Av., 10.031
Av.,	1.0310 + 246.9831	1.0310 + 246.9835	248.030 — .015	11.30	52.8	239.981
				12.00	52.9	
				12.30	52.8	
Cor. av.,	248.0141	248.0145	248.015	1.00	52.8	Cor. av., 250.012
	247.0345	247.0345	247.0345	1.30	52.8	
				2.00	52.8	
Head on weir,	.9796	.9800	.9805	2.30	52.8	
				3.00	52.9	
				3.30	52.8	
				4.00	52.8	
				4.30	52.8	
				5.00	52.8	
				5.30	52 8	
				6.00	52.8	
				6.30	52.4	
				7.00	52.4	
				7.30	52.4	

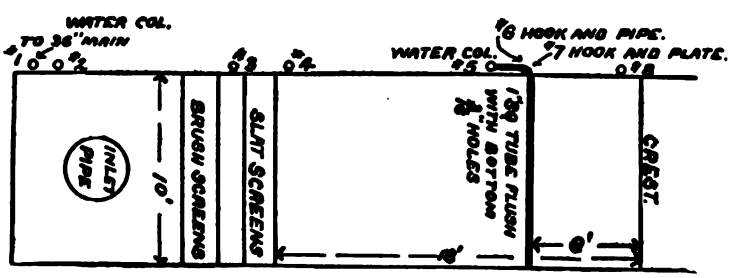

FIG. 4. SKETCH OF WEIR.

Mean height, floor to crest, 5.061′. Mean elevation of crest of weir, 247.0345′.

[1] Hourly averages from 10 A. M., May 1, to 9 A. M., May 2.

ENGLACIAL DRIFT.[1]

By W. O. CROSBY, S.B.

Received April 15, 1896.

INTRODUCTION.

AMONG the unsolved problems of glacial geology none, perhaps, are more important or pressing at the present time than the relative abundance and significance of the englacial drift. Although this subject has received its due share of attention in the recent literature of the science, the views of the leading glacialists are still strongly contrasted. Thus Chamberlin and others hold that the englacial drift was exceedingly scanty in amount, consisting chiefly of a few far-traveled, angular, and unglaciated bowlders now scattered over the surface of the drift; while Upham, the foremost exponent of the opposing theory, finds in the englacial drift the chief source of all the manifold forms of modified drift and also of drumlins.

The arguments of those who minimize the englacial drift are based chiefly upon the local character of the drift, the supposed paucity of englacial drift in modern glaciers, and the mechanical difficulty of accounting for a differential upward movement in the ice-sheet whereby large volumes of basal drift or ground moraine became englacial. The cogency of these arguments is beyond question; and a careful study of the recent literature satisfies me that, as the case now stands, the *onus probandi* may fairly be said to rest upon those who regard the englacial drift as an important factor in Pleistocene geology. Still, the englacial drift accounts so satisfactorily for far-traveled erratics, and the derivation from it of the modified drift is, theoretically, so relatively direct and simple, that faith in its sufficiency cannot be lightly relinquished.

In his recent paper on the "Discrimination of Glacial Accumulation and Invasion,"[2] Upham has, it seems to me, made a substantial

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[1] Reprinted from American Geologist, 17, No. 4, April, 1896.

[2] Bull. Geol. Soc. of America, 6, 343-352.

contribution to the general theory of the Pleistocene ice-sheet; and my chief purpose now is to analyze this idea that the ice-sheet was, over a considerable part of the glaciated area, formed *in situ* by snow accumulation, trace it to its logical conclusions, and show that it also throws important light upon the more special problem of the englacial drift.

Probable Early History of the Pleistocene Ice-sheet.

In this discussion a sharp distinction may properly be made between mountainous tracts, like the Adirondacks, Green Mountains, and White Mountains, and the plain or peneplain surface characteristic of the greater part of the glaciated area. The first-named topographic type, although the more exceptional, may conveniently be considered first.

In mountainous districts, or where the relief features are so strongly accentuated as to cause appreciable climatic differentiation, the general refrigeration of the climate, due chiefly, it is probable, to a marked elevation of the northern part of the continent, led first to the development of glaciers of the Alpine type in the higher valleys. These descended, under the influence of gravity, below the climatic zone in which they originated; as the level at which terminal ablation balanced the downward movement was gradually lowered, they became confluent; and finally, emerging from the mountains, they deployed upon the plain country, forming relatively sluggish or stagnant piedmont glaciers. But the extension of the piedmont glaciers by simple invasion cannot continue indefinitely, for the reason that with progressive refrigeration the annual snowfall finally exceeds the annual melting over the plain country as well as the mountains; at first near the margins of the piedmont glaciers only, but gradually extending farther and farther from them.

This cumulative snowfall, which mantled alike hills and valleys, and changed slowly through *névé* to glacial ice, must have tended in some measure to check or arrest the motion of the ice which had flowed outward from the mountains. Owing, however, to the forward motion of the piedmont glaciers, as well as to their termination on tracts where a short time before ablation had been in excess of snowfall, they must have terminated somewhat abruptly or with high marginal gradients;

and the conditions were, therefore, extremely favorable for their overriding the new and still stationary ice-fields by which they were invested, in the manner indicated by the experiments of Favre, Bailey Willis, and others, on the compression and folding of sedimentary deposits of unequal thickness or rigidity.[1] The overridden tract or zone of ice must slowly acquire the motion of the overriding sheet, and thus in its turn come to override other tracts. In fact, it seems to me very probable that this process of overriding and absorption would continue almost indefinitely, extending, possibly, over a large part of the glaciated area. The only alternative views are that the piedmont glaciers became stationary, or that they were able by simple thrust to induce motion in the embryo and still sedentary ice-sheet across a breadth of hundreds of miles. The theory of overriding lies between these extremes.

Assuming a uniform annual snowfall over the area of the sedentary ice-sheet, it is obvious that since its area is gradually extended southward by the progressive climatic refrigeration, while the annual ablation as gradually diminishes northward, its thickness must increase backward from the margin. To the surface gradient thus resulting must be added the southward gradient of the surface of the land, which was probably augmented by differential continental uplift.

If, as Upham holds,[2] and as certainly seems most probable, the precipitation of snow over the growing ice-sheet was not uniform, but greatest for the first one hundred to two hundred miles inward from the margin, the surface gradient must have culminated on these peripheral tracts, diminishing gradually backward. This condition would, obviously, favor an early beginning of outward movement or flow in the marginal zone, and tend in an equal degree to retard motion in the central area.

It seems a reasonable assumption that the period of the growth and culmination of the ice-sheet, equally with that of its waning and disappearance, must have witnessed marked climatic oscillations of long period. In fact, we would hardly be justified in supposing that the great crustal movement which gave us the Ice Age was steadily progressive, without interruption or reversal, until its final culmination.

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[1] See, also, Upham's paper on "Drumlins and Marginal Moraines of Ice-sheets," Bull. Geol. Soc. of America, 7, 22.

[2] Bull. Geol. Soc. of America, 6, 344.

During each period of climatic amelioration and increased ablation of the sedentary ice-sheet its margin must have retreated to the northward; and since the ablation must have rapidly diminished northward, snowfall exceeding ablation within a few miles of the margin, we have here another efficient cause of a high marginal gradient; that is, precipitation and ablation coöperate to accentuate the frontal slope of the ice-sheet. Now, the chief factors in determining movement of the ice-sheet were, undoubtedly, its thickness and marginal gradient. We have few reliable data derived from observations on modern ice-sheets to indicate the magnitude which these factors must attain to inaugurate movement in an ice-sheet formed *in situ* over such a dissected peneplain as is presented by the surface of a large part of Canada and the northern United States, many of the valleys having contrary or transverse directions. But the absence from a large part of the glaciated area of mountains or dominant heights of land requires us to assume that over considerable tracts the sedentary ice-sheet did eventually begin to flow without having experienced the overriding or shearing thrust of the piedmont ice-fields. The outward movement thus originating in the peripheral tracts during a period of excessive ablation must have extended backward, perhaps until it met the forward thrust of the piedmont glaciers.

During a period of active growth of a sedentary ice-sheet each annual snowfall advances its margin, and increases its thickness by amounts depending upon the distance from the margin. Although the zone of maximum precipitation does not necessarily coincide exactly with that of most rapid growth or maximum excess of precipitation over ablation, we may assume that they would not be widely separated, and that the locus of most rapid growth would, therefore, be found at a moderate distance, say one hundred to two hundred miles from the margin. If we could only know the normal ratio of vertical to horizontal or areal growth, we might, assuming that climatic oscillations began at an early period of its history, reach a definite conclusion as to the probable extent of the ice-sheet when it first began to move or flow outward. We may, however, attack the problem in another way. The equivalent of one foot of ice is, perhaps, not too large an estimate of the average annual excess of precipitation over ablation on the zone of maximum growth. Warm periods may arrest and reverse the areal growth while the central tracts continue to increase in thickness, though possibly at a diminished rate, thus

accentuating the frontal slope; that is, while cold periods must mean, on a plain country, relatively rapid horizontal growth and therefore a growth unfavorable to early movement, the ice-sheet becoming proportionally thinner, a moderately warm period following a cold one means continued growth in thickness with a great reduction of area and hence a growth especially favorable to early movement, the ice-sheet becoming proportionally thicker. It seems probable, therefore, that a warm period following a cold period of two or three thousand years duration would induce movement in the sedentary ice-sheet, and that movement at this early period might affect almost simultaneously the peripheral and central tracts.

Assuming now that movement of the ice-sheet was inaugurated during a warm period, and that the southern margin of the ice has retreated far to the north through ablation, developing a bold and aggressive front, it is obvious that the succeeding cold period must have caused a rapid extension of sedentary ice southward from the front of the moving sheet, and the former would inevitably be progressively overridden and absorbed by the latter. It may be noted, also, that these phenomena would be repeated with each recurring climatic cycle. This section may be summarized as follows:

The Pleistocene ice-sheet was formed *in situ*, by snow accumulation, over the main part of the plain country within the glaciated area. The motion which this sedentary ice-sheet subsequently acquired probably originated in several ways.

1. In the vicinity of the mountainous tracts, through its being progressively overridden and absorbed by piedmont glaciers.

2. At a distance from mountains and independently of piedmont glaciers, by the steepening of the marginal gradient, chiefly through increased ablation due to climatic amelioration.

3. The cold period following each period of marked climatic amelioration and consequent recession of the margin of the ice-sheet must have spread a new sedentary ice-sheet over the deglaciated area, which would be progressively overridden and absorbed by the re-advance of the older sheet.

Basal Relations of a Sedentary Ice-sheet.

During the slow accumulation of the ice-sheet, and before it began to move, the ground beneath it, which must have been saturated with water, was probably frozen solid to a considerable depth, possibly

nearly if not quite to the bottom of the residuary soil or other surface detritus; that is, down to the firm rocks. There could have been no original plane of separation or movement between this frozen soil and the overlying ice-sheet, for the ice did not merely rest *on the detritus*, but extended down through it to the lower limit of frost. This point will probably be conceded by all who have noted the tenacity with which ice in winter adheres to the ground, pavements, etc., when the temperature is below freezing.

Ice, in the thin sheets with which we are familiar, separates readily from the underlying soil in mild weather, while the subsoil still remains frozen, for the simple reason that the solar heat passing downward through the ice is arrested by the surface of the ground, causing a local rise of temperature along the contact between the ice and frozen soil. The operation of this principle evidently depends upon the thermal diaphaneity of the ice, and hence it does not in general admit of application in the case of snow, which is relatively opaque to both light and heat. Therefore, this cause of separation cannot be invoked in the case of the growing ice-sheet of the Glacial Period, since it was a necessary condition of its formation that the winter snows remained unmelted upon its surface, accumulating thus to a great thickness and slowly changing downward through *névé* to glacial ice. We must suppose, then, that from the top of the ice-sheet to the lower limit of frost in the soil was one solid mass — ice above and ice and soil below.

It may safely be assumed that over the glaciated area in preglacial times, as now in lower latitudes, the superficial detritus or soil was chiefly the residuary product of quiet chemical decay. This is equivalent to saying that it consisted chiefly of clay and sand. Hard, angular fragments of rock, such as are so common in the till, were wanting, and the rounded, bowlder-like nuclei of decomposition must have been of rather rare occurrence at points near the surface of the ground or above the lower limit of the frost.

If we may assume a thickness of residuary detritus commensurate with that which now mantles the Southern States, it is, perhaps, probable that over considerable areas solidification by freezing would fail to reach the firm, undecomposed rocks beneath. However that may be, it is certain that with increased thickness the ice-sheet became a more and more efficient protection to the ground against the climate of the Ice Age, and the steady efflux of heat from the earth's interior would

thus tend to gradually loosen the hold of the frost upon the rocky substratum.

Observations in the arctic regions and at high altitudes show that the ground may become frozen to a depth of several hundred feet, and R. S. Woodward's theoretical discussion[1] of the subject not only corroborates these observations, but indicates that the downward penetration of the frost may be comparatively rapid. Thus if the mean annual temperature of the surface should fall from 60° F. to 10° F., the ground would become frozen to a depth of 400 feet in less than one thousand years. Russell suggests[2] that the great depth of frozen soil reported at Yakutsk, Siberia (382 feet), and at other arctic stations, may be due in part to the surface accumulation of ice through the growth of the tundra, and that possibly the rate of diffusivity of temperature assumed by Woodward is too high, but he does not seriously question the main conclusion with regard to the efficiency of frost penetration.

It is well known that glaciated areas are not in general those of most extreme cold. A humid climate is the first essential; and, given that, a temperature low enough throughout the year to insure precipitation chiefly in the form of snow and to prevent excessive waste by summer melting — a mean annual temperature a few degrees only below freezing, like that on the Mount St. Elias coast of Alaska — is all that is required for active glaciation. In harmony with this conclusion, we find that the extremely frigid areas, such as the interior of Alaska and northern Siberia, are relatively dry and non-glaciated. For this reason, and also because the increasing thickness of a sedentary ice-sheet would tend to neutralize the downward penetration of frost, we need not suppose that the ground beneath the ice would be frozen to any great depth or far below the detrital layer.

The relatively high conductivity and diffusivity of pure ice, in comparison with the covering of *névé* and snow, would tend, through the steady efflux of the terrestrial heat, to raise the temperature of the lower portion of the ice-sheet to the melting point. On the other hand, the high latent heat of fusion would tend to prevent extensive melting of the ice until the entire basal portion of the sheet had attained approximately the melting temperature. The effect of the

[1] Bull. Geol. Soc. of America, 1, 130–132.

[2] Ibid.

weight of the ice itself in lowering the temperature of fusion of its base would be too small to require consideration here.

The interesting question now arises as to the most probable plane of shearing when the sedentary ice-sheet finally begins to move. We may assume that the initial basal shearing or gliding plane will be approximately the same whether the ice-sheet begins to move in obedience to its own weight or through the overriding thrust of a thicker northern sheet. In any case, or whatever the cause of movement, it is, as we have seen, most likely to be inaugurated during a period of climatic amelioration. Above the bed-rock, three layers of material require consideration: (1) The ice-sheet proper; (2) the frozen soil beneath it, to which it is still firmly united; (3) the unfrozen soil resting upon or passing downward into the solid rocks. Under the assumed conditions of climatic amelioration and a basal rise of temperature in the ice-sheet, we may suppose that the frozen soil, in consequence of its lower position and the relatively low specific heat of earthy and stony substances, would tend to rise in temperature and to thaw earlier than the pure ice. Hence the frozen soil may, perhaps, be regarded as weaker and more susceptible of shearing than the clear ice, although at temperatures well below freezing the reverse relation would probably hold true. We thus arrive at the conclusion that at the inception of movement in any part of the ice-sheet the ice is possibly stronger than, but essentially continuous with, the frozen soil, and the latter is clearly stronger than the unfrozen soil; and hence it would follow that the most probable initial plane of slipping or shearing would be in the unfrozen soil, the frozen soil and overlying ice moving *en masse*, and the movement being lubricated by the unfrozen soil, which would be at most points of an argillaceous and plastic character. Although a residuary soil naturally becomes firmer and more rock-like downward, and is, therefore, weakest near the surface, we should not lose sight of the fact that, since frost causes a notable expansion of the soil, a recession of the lower limit of the frost toward the surface, through the efflux of the terrestrial heat and consequent rising of the isogeotherms, would tend to leave at the lower surface of the frozen soil a thawed-out layer of loose and yielding texture.

Observations heretofore made on modern glaciers and ice-sheets are of little value in this connection, because nowhere in the field of observation are realized the conditions that must obtain at the base

of a sedentary or recently sedentary ice-sheet. The true glaciers or ice rivers of Alpine districts, Greenland, etc., are mere lobes of ice descending under the influence of gravity from the edges of *névé* fields and ice-caps into a climatic zone where permanent ice cannot form; and hence they are moving over unfrozen soil, and the ice is wasting by melting on its under as well as its upper surfaces. The great *desideratum* is, evidently, a shaft or boring in the interior of Greenland extending through the entire thickness of the ice-sheet and a hundred feet into its rocky bed. This would expose the true basal relations, thermal and otherwise.

In his recent paper on the "Influence of Débris on the Flow of Glaciers,"[1] Professor Russell assumes that ice is analogous to pitch in that its plasticity or tendency to flow is diminished by inclosed *débris*. This assumption is undoubtedly safe for temperatures well below freezing. But if it is a sound principle that when the temperature of the ice is rising and near the melting point the inclosed rock *débris* will, on account of its lower specific heat, tend to rise in temperature faster than the ice and thus to loosen by melting the bonds between it and the ice, then the comparison with *débris* in pitch would seem to hold good only in the improbable case when the imbedded stones caused a local softening of the pitch. The *débris* in ice would not lead to extensive melting, on account of the high latent heat of melting ice. But if the temperature of the *débris* rises ever so little above 0° C. (32° F.), it ceases to be a source of strength in the ice, the effective section of the ice being diminished in proportion to the amount of *débris*. This view seems to be abundantly confirmed by Professor Chamberlin's Greenland studies, for he has given us no more striking and significant fact than the relative facility with which the ice shears along innumerable lines of *débris;* and the evidence is conclusive that the ice, to a large extent, slides over the inclosed *débris*, instead of dragging it along, as it would if the *débris* were firmly frozen into the ice Granting, however, that the frozen soil would be more rigid and indifferent to gravitative stresses than the clear ice above it, the fact remains that the unfrozen soil at the base is more yielding and plastic than either; and hence, although we may reasonably conceive definite shearing planes as distributed through a considerable thickness of the ice-sheet, the lowest plane, and the true base of the ice-sheet, will still be at the lower limit of frost.

[1] Journal of Geology, 3, 823–832.

So far as I can learn, everywhere within the range of observation modern glaciers are either sliding over their ground moraines or they rest directly upon the firm bed-rock, just as many rivers, at ordinary seasons, flow quietly over deep beds of gravel and stones or over bare ledges. In both cases active erosion of the bed-rock floor is nearly at a standstill, for where it is not protected by the stagnant *débris* the ice or water are not well suppled with stones, without which they can do little. In the case of the river, periods of flood or of greater fall or volume in the past must be postulated to set the detritus in motion and account for the effective erosion of their channels. Similarly for the glacier, the entire ground moraine must be set in motion. Increased thickness and velocity of the ice would probably tend to accomplish this. But to my mind rectilinear striæ, often scores of feet in length, are an impossibility unless we conceive the entire mass of the ground moraine as inclosed in the moving ice.

Professor Chamberlin's observations in Greenland show that any number of horizontal shearing planes may be postulated, with a corresponding reduction of the basal velocity; but I see, with Upham, no escape from the conclusion that during the period of active and efficient glaciation of the bed-rock surfaces the ground moraine was very scanty or wholly wanting, being incorporated with the moving ice. Imagine a modern glacier or ice-sheet as launched upon a plain covered by 25 to 50 feet of sedentary detritus passing gradually downward into firm rocks, and consider how little chance there would be for the development on the underlying bed-rock of a typical glaciated surface so long as the ice and soil are essentially distinct. The preliminary removal of the detritus by simple thrust and drag is seen not to be a valid explanation when we consider the great breadth of the glaciated area and the enormous marginal accumulation which would inevitably result. A true ground moraine between bed-rock and ice, and distinct from both, belongs to the waning stage of the ice-sheet and to lobes of ice (glaciers) descending from an ice-cap or *névé* field into a climatic zone where permanent ice cannot form.

All this appears to be quite consistent with the local origin of the greater part of the till or ground moraine of the Pleistocene ice-sheet and the well-established fact that the total movement of the ice amounted to hundreds of miles if we simply suppose that through the granular plasticity of the ice, or a series of shear planes, the basal, drift-laden layer moves much more slowly than the overlying clear ice.

Absorption of Drift by the Pleistocene Ice-sheet.

Glacialists are sharply divided in opinion as to the power of an ice-sheet to absorb or incorporate with its mass the detritus over which it moves, and the arguments *pro* and *con* have been stated with much fullness and force in recent papers by Upham, Chamberlin, and others.[1] It is clearly incumbent upon the advocate of the englacial theory to prove that large volumes of drift may become englacial. It seems to me that this has not been satisfactorily done as yet, and, as previously stated, the chief purpose of this paper is, if possible, to reinforce the englacial theory at this point.

The sedentary ice-sheet, as we have seen, holds in its grasp a large part of the surface detritus; and if, as I believe, the initial shearing plane is normally or usually at the lower limit of frost, a considerable body of detritus, mostly of a fine or impalpable character (preglacial residuary soil, etc.), is englacial from the beginning of movement of the ice-sheet. When a sedentary ice-sheet is overridden by a piedmont glacier, and still more when a sedentary ice-sheet is overridden by the re-advance of an earlier ice-sheet, the conditions must be favorable for the transfer of drift from the base of the earlier sheet to a somewhat elevated position in the composite sheet which results from the overriding. We may suppose that the overriding sheet will carry with it not only its own englacial drift, but will drag along, also, a part of its ground moraine or subglacial drift. This complex process will be repeated with each marked recession and re-advance of the ice-sheet.

It is altogether probable that each important recession of the ice-sheet, and not alone the final recession, was characterized by numerous glacial rivers and lakes and an extensive development of modified drift in the well-known forms of kames, eskers, deltas with abrupt northern margins, etc. It is obvious that such eminently loose and porous deposits would be completely permeated by and form an essential part of the succeeding sedentary ice-sheet. Thus material which may have slowly become englacial through the movement of an earlier ice-sheet is englacial from the beginning of the succeeding sheet; or, if the later ice should move over these deposits, their forms and structures are very favorable to their being absorbed by the ice through shearing and flexing.

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[1] Upham has recently cited all the more important of the later contributions to this discussion. Bull. Geol. Soc. Amer., 5, 72, 73.

Some of the illustrations accompanying Professor Chamberlin's valuable description of the Greenland glaciers[1] are well calculated to dispel any doubts that may exist in the minds of geologists as to the power of a glacier to absorb detritus by shearing and flexing movements. The flexures are certainly very remarkable, considering that, strictly speaking, ice is neither viscous nor plastic. Chamberlin's explanation of movement as the result of granulation and a continuous adjustment of the granular structure to gravitative stresses through differential melting and regelation obviates in a measure the difficulty of accounting for the complex movements observed; but the fact remains that relatively slight obstructions, whether of solid rock or uncompacted drift, are sufficient to originate sharp overthrust flexures and obliquely ascending shear planes, which are marked by prominent bands of *débris*—ground moraine in process of absorption by the ice. To Chamberlin belongs the credit of observing and depicting more clearly, perhaps, than any previous writer the mechanism of the transfer of drift from a subglacial to an englacial position. There can be no doubt now that in a lee the ice, at least under certain conditions, will drag, in consequence of basal friction, sufficiently to give rise to a sharp flexure or a thrust fault between it and the ice which passes over the obstruction. A part of the latter is being constantly curved downward and backward and added to the stagnant ice, and thus the thickness of the latter increases with the distance from the lee slope, and the axial plane of the flexure rises to higher levels in the ice; or, if the conditions of granulation, velocity, etc., determine shearing as well as or instead of flexing, the shearing plane will likewise tend to rise in the ice.

In an earlier publication[2] Professor Chamberlin has analyzed glacial motion and shown the importance, in a detailed study, of distinguishing vertical pressure, due to the thickness and weight of the ice, and flowage pressure, due to its horizontal movement. The former culminates in the basal central and the latter, as a rule, in the superficial peripheral tracts. These two pressures coöperate on stoss slopes, and hence glacial erosion reaches its maximum intensity there. Glacial striæ record, almost exclusively, the movements of the ice-sheet in its final stages, and it is well understood that the general absence of

[1] Journal of Geology, 3, 478, Figs. 28–30, Bull. Geol. Soc. Amer., 6, 203–214, plates 5–9.

[2] Seventh Ann. Report, U. S. Geol. Surv., 186–192.

striæ on lee slopes above a certain low angle of declivity means that the flowage pressure then so far predominated over the vertical pressure that the ice tended to arch over the lee slope instead of flowing down it. Under the greater vertical pressure and lower velocity of the central areas the ice will hug the lee slopes more closely, and they will be more generally glaciated. In this case, however, as truly as in the first, the ice in the lee must drag — that is, move more slowly than the ice above it; and this retardation will almost inevitably, according to Chamberlin's Greenland observations, lead to flexing or shearing and the absorption of detritus. We are thus brought to the conclusion that from the summit or crest of nearly every elevation with an abrupt lee slope a stream of detritus flowed onward and upward into the Pleistocene ice-sheet during its progress over the land. And it is obvious that, if this view be even measurably sound, the mechanism is provided for the abundant transfer of drift from a subglacial to an englacial position. This important conclusion may be presented in another way. The detritus urged up or worn from the stoss slopes by the movement of the ice clearly did not descend the lee slopes under the pressure of the ice, else these slopes would not be unglaciated; therefore it must have passed on into the ice, or else have accumulated in a passive form on the lee slopes. It was probably disposed of in both these ways, but it is well known that stoss slopes are quite as likely as lee slopes to be encumbered by ground moraine.

The recently published experiments in ice motion made with wax by E. C. Case[1] have a special interest in this connection. They tally very closely with Chamberlin's Greenland observations, and materially strengthen our general conclusion that the forward motion of the ice over an uneven topography gives rise to obliquely ascending currents and that from the summits of elevations basal detritus is carried, not down the lee slopes, but forward and upward into the body of the ice.

It must, however, be conceded by the englacialist that during the period of maximum glaciation for any area, when the ice was thickest and the vertical pressure had its maximum value, a large proportion of the drift reaching the top of stoss slopes probably remained in the bottom of the ice and was dragged down the lee slopes and away from the elevations without losing its subglacial position. This must have involved the striation and polishing of the lee slopes, and the condi-

[1] Journal of Geology, 3, 918–934.

tions were unfavorable for the detachment of blocks of rock — the rending and quarrying operations of the ice-sheet. Later, when the vertical pressure was less and the velocity of flow greater, the ice hugged the lee slopes less closely, and the conditions became favorable for the detachment of blocks by the ice moving under the combined vertical and flowage pressure across the crests of the elevations. If the ice actually pulled away from the lee slopes to an appreciable extent, or even tended to do so, the local relief of pressure may, perhaps, have led to the freezing on these slopes of subglacial water. This sedentary ice, penetrating the joint cracks of the rocks and by its expansive power starting the joint blocks from their positions, and later, by its continued growth, becoming continuous with the moving ice, may have assisted in plucking away blocks and fragments of rock from the lower as well as the upper portions of the lee slopes, thus tending to maintain the high angle of declivity so characteristic of lee slopes.

The broken and precipitous character of typical lee slopes is, to my mind, rather inconsistent with the passage down them, during the detachment and removal of the blocks, of much ground moraine; and this conclusion is in harmony with the facts that they are not now, as a rule, banked high with till and that we often find a surface train of angular blocks leading away from them. That the blocks thus borne away from a lee slope were, in many cases, carried in the ice instead of being dragged along beneath it is proved by the occurrence of entirely angular and unglaciated forms and the fact that, as in the case of the great Madison bowlder in New Hampshire, the original orientation of the blocks is sometimes unchanged.[1]

In the preceding paragraph I have but followed in the footsteps of Professor Chamberlin, for he has shown[2] very fully and clearly that the ice flowing over and around prominent ledges and rocky hills will naturally carry away in true englacial fashion many angular blocks and more or less of other forms of detritus, and also that this, as he supposes, scanty englacial drift is now distinguishable from the ground moraine on which it rests. Having granted this much, Professor Chamberlin is, apparently, obliged to ground his argument for the essential scantiness of the englacial drift upon the assumption,

[1] Appalachia, 6, 66.

[2] Journal of Geology, 1, 47–60 and 255–267.

nowhere explicitly stated, that but little drift was dragged or carried by the ice up the stoss slopes and over the crests of the ledges and hills, for this material would obviously have an equal or better chance than that worn from these elevations of becoming truly englacial. But the validity of this tacit assumption cannot be admitted. The severe glaciation of the stoss slopes is against it; and, aside from this consideration, it is difficult to understand how, except in valleys trending with the glacial movement, any considerable amount of detritus that was transported or dragged a good fraction of a mile or more from its source could help crossing one or more elevations. Certainly its course would need to be very devious to avoid them.

Again, Professor Chamberlin[1] has given us the important principle that, during the closing stages of the Ice Age at least, the surface of the ice-sheet must have been depressed over highlands and elevated over valleys, and that, movement being determined by surface gradient alone, the ice would flow toward rather than from the highlands. This principle would thus operate to increase the ground moraine on the hilly tracts at the expense of that in the valleys and lowlands; and it has occurred to me that perhaps we have here an explanation of the long, ridgelike accumulations of till which often, on the plain country, border or separate the north-south valleys. Just as a river does not make its chief deposits in the deepest part of its channel, where the current is strongest, but along the margin, building up the flood plain, so the ice stream tends to crowd the detritus out of north-south valleys from the line of swiftest to the lines of slowest motion. From these till ridges we pass easily and naturally to drumlins. Every glacialist knows that the drumloid slopes of till, which may, in my opinion, be regarded as embryo drumlins, although most characteristic of stoss slopes, occur abundantly on lee slopes also. They seem to indicate an attempt on the part of the ice-sheet to carry or drag a large amount of drift up the stoss slopes. When the drift gains the crest it is in part carried away into the body of the ice by the freer motion of the ice above this level, tending to leave the lee slopes bare, as already noted. But during the waning of the ice-sheet its movement over the rock hills and ledges finally became so feeble that it could no longer urge all the subglacial drift, the amount of which was probably being augmented by basal melting, up the stoss

[1] Seventh Ann. Report U. S. Geol. Surv., 184, 185.

slopes, and it began to accumulate upon them. Each increment was so thoroughly compacted and pressed down by the ice, aided by the natural tenacity of the clay, that the effective stoss slope was gradually raised until the accumulation of till finally overtopped the rocky obstruction and became a drumlin. This view seems to be in entire accord with Professor Chamberlin's recent suggestion with regard to the origin of drumlins.[1]

Perhaps the general conclusions to which my studies have now led me may be best stated as follows: A large part, probably the main part, of the preglacial surface detritus was englacial in the sedentary ice-sheet and remained so after the ice began to flow during the entire period of the growth, culmination, and early decline of the ice-sheet, or while the hard bed-rock surface was being actively abraded and striated. During this time, which embraced the greater part of the Glacial Period, the preglacial detritus not originally incorporated in the ice and the material worn from the ledges by the ice itself became englacial, in large part at least, through overriding, shearing, and flexing movements of the ice, a hard surface of drift-shod ice in direct contact with the uneven bed-rock surface appearing to be essential to the rectilinear striation of the latter. During the later stages of the decline of the ice-sheet basal melting set free considerable volumes of the hitherto englacial drift to form the ground moraine; and just as the frontal or terminal moraine, also composed of material set free by the ablation of the ice, records the cessation of the forward movement or invasion of the ice-sheet, so the basal or ground moraine records the gradual cessation of the glacial abrasion of the bed-rocks. The relative suddenness of this change from active erosion to deposition in any area is indicated by the fact that, generally speaking, the ground moraine rests everywhere upon normally striated surfaces. In other words, as soon as the ground moraine began to appear through basal melting it was essentially motionless, for ice moving over a bed of detritus in a way to impart motion to it would inevitably give rise to sidewise, oblique, and devious movements of individual stones which would tend to obscure and efface the rectilinear striation of the bed-rock surface. The ground moraine as it accumulated was pressed down by the ice to form the typical hardpan. In part it accumulated on stoss slopes through obstruction to, and in part on lee slopes

[1] Journal of Geology, 3, 480.

through protection from, the forward movement of the ice, forming drumloid slopes and, later, drumlins.

It is not a necessary deduction from this view that the bed-rock always rises to a good height in drumlins, since the hardpan character of the ground moraine and the tendency of the ice at this stage to flow over loose materials, as observed by Niles, Spencer, Chamberlin, and many others, make of the initial knob or boss of the ground moraine an efficient gathering point for more material as fast as it is furnished by the melting of the ice. The main point may be presented in another way. When, as in the earlier and maximum stages of the ice-sheet, the basal temperature was below freezing, the freezing of subglacial waters made and kept the detritus a part of the ice-sheet; and when, as in the later stages of the ice-sheet, the basal temperature rose above freezing, the ice relaxed its hold on the detritus and flowed over it, as attested by observations on modern glaciers.

It is a necessary consequence or corollary of this view that transportation of drift by simple drag is relatively unimportant, if not impossible. The transportation is almost wholly englacial, as insisted by Upham,[1] but highly differential, being extremely slow in the basal layers and more and more rapid at higher levels. The detritus reaching the highest levels in the ice is carried farthest, not only because of the higher velocity, but also because it remains for a longer time in the ice.

The history of an ice-sheet embraces, as regards the basal temperature, two distinct and contrasted periods: (1) The period of growth and maximum development, when the temperature of the lower part of the ice is permanently below freezing; (2) the period of decline, when the basal temperature is above freezing. The first is the period of active abrasion and scoring of the bed-rock, all detritus being frozen into the ice as fast as formed. Furthermore, the water resulting from superficial summer melting of the ice, descending through crevasses to the basal portion of the sheet and refreezing there, not only adds the newly formed detritus to the base of the moving sheet, but also, perhaps, favors an actual downward growth of the ice-sheet, whereby detritus which has previously become englacial is raised to greater heights in the ice, the growth of the ice-sheet being chiefly upward by snowfall in winter and downward by basal freezing in summer.

[1] Bull. Geol. Soc. Amer., 6, 348.

During the second period the ice-sheet wastes by basal as well as superficial melting, the englacial drift becomes subglacial (ground moraine), and glacial erosion gradually ceases.

The prevailing opinion among geologists, as recently collated by Culver,[1] is evidently strongly against the efficiency of glacial erosion, and this trend of opinion is certainly justified so far as it is based upon observations on living glaciers. Observations on the velocity and abrasive power of modern ice-sheets have never been made. But the relatively high efficiency of the Pleistocene ice-sheet in this respect is clearly proved by the undisputed facts that over practically the entire glaciated area north of the terminal moraine *all* the preglacial sedentary soil and partially decayed rock were worn away, involving on a large aggregate area extensive erosion of the hard, unaltered rocks, and that the prevailing color of the ground moraine below the sharply defined limit of postglacial oxidation is that of crushed rock, and not of residuary or other preglacial detritus. The latter fact, which seems to have been but little regarded, is probably of equal significance with the first, and the general conclusion based upon both these is further sustained by observations upon the proportions of distinctively glacial detritus in the ground moraine.[2] It is a logical deduction from the view developed here that there can exist in the ground moraine, in general, no real or definite distinction between subglacial and englacial till, because, broadly speaking, it has all been englacial.

Probably no feature of the Greenland glaciers revealed to us by Chamberlin's studies will be regarded by glacialists with greater interest and astonishment than the beautiful stratification and lamination of the ice. He states, and his photographic illustrations show, that the stratification is most perfect in the lower, drift-laden portion of the ice, being only obscurely seen in the upper white ice. It is especially interesting to note in this connection that in the drift-laden ice the stratification is due chiefly to the mode of distribution of the drift or rock *débris*, which forms numerous relatively thin and continuous layers approximately parallel with the bottom of the glacier and often exhibiting flexures and faults where the ground over which the glacier moves is sufficiently uneven. Chamberlin refers all this englacial drift

[1] Trans. Wis. Acad. Sci., etc., 10, 339–366.

[2] Proc. Boston Society of Natural History, 25, 131–138.

to one source. It is ground moraine which has been absorbed by the ice through flexing and shearing movements, and it proves that this process of absorption is essentially continuous. The thinness and persistence of the layers of *débris* also prove that the planes of shearing extend forward indefinitely into the body of the ice, and do not tend to die out, as they would if the ice were a viscous or plastic substance. This differential movement along an inset layer of *débris* must drag it out and tend to give it persistence, even if the process of absorption in that plane is intermittent.

Furthermore, we find here a most striking confirmation of the conclusion previously stated, that, under certain conditions at least, the *débris* in the ice is an element of weakness and tends to give rise to shearing and gliding planes. This whole process of lamination by shearing is beautifully attested by the marked projection of the upper layers on the precipitous margin of the ice due to ablation. The under surfaces of the projecting layers are fluted by the fragments of rock lying in the plane of shearing. But in spite of this indication that the ice moves over the inclosed detritus, it is obvious that the movement must also drag it along; and when we consider how intimate this process of lamination shearing is, producing in extreme cases as many as twenty distinct layers in an inch, it can hardly be doubted that the englacial rock fragments, more especially if of small size, must suffer faceting and striation after the manner of the ground moraine. Thus one supposed distinction between subglacial and englacial drift in a measure disappears, and is no longer available as an argument to minimize the englacial drift of the Pleistocene ice-sheet.

Professor Chamberlin has noted[1] that while the Greenland glaciers commonly slide over the ground moraine in their lower courses, allowing it to accumulate beneath them, they appear in their upper courses to drag and carry it along, fitting snugly in their respective valleys and scoring the ledges over which they move. By parity of reasoning we may suppose that, although at its lower extremity the ice is observed to slide over the interstratified *débris*, farther back from the margin the *débris*, being frozen in the ice, is urged along and glaciated by the motion of the ice.

I have observed something analogous to this lamination shearing of

[1] Journal of Geology, 3, 67 and 208–210.

glacial ice in the obsidian flows of the Lipari Islands. In consequence, perhaps, of incipient crystallization, or of partial relief from pressure, due to the fact that the lava continued to flow after it had begun to stiffen, imprisoned or dissolved aqueous vapor is liberated along certain planes coincident with the plane of flowing, giving rise to layers of vesicles. These vesicular layers (analogous to *débris* layers in the glacier) become, with continued stiffening of the magma, relatively planes of weakness and hence shear planes — a true flowing movement which affects the entire body of magma being transformed in part, by continued pressure from behind, to mechanical shearing along definite planes.

Comparison with Modern Glaciers and Ice-sheets.

Perhaps the most cogent argument against the view that the drift of the Pleistocene ice-sheet was, during certain prolonged phases of its history, largely or chiefly englacial is that based upon the comparative rarity of englacial drift in modern glaciers and, seemingly, in modern ice-sheets. The general freedom of glaciers of the Alpine type from incorporated drift, other than that derived from lateral and medial moraines through the agency of crevasses, is, no doubt, attributable to the facts that their courses were long since swept relatively bare of detritus and that in their lower courses they are undergoing basal melting, and hence depositing rather than absorbing drift.

According to the observations of Chamberlin and Salisbury,[1] the numerous glaciers descending from the margin of the Greenland ice-cap present, in this respect, two types: (1) The drift-laden glaciers, which have commonly vertical sides and ends and predominate north of latitude 76°; (2) the apparently drift-free glaciers, which are commonly without prominent vertical sides or ends and predominate south of latitude 76°. Both these able observers state emphatically that in the drift-laden glaciers the drift is strictly a basal feature, rarely rising to greater heights in the ice than 100 to 150 feet even where the glacier may be a thousand feet or more in thickness. Furthermore, these observations are regarded as fully confirmed by those made upon the countless icebergs of the neighboring seas. We may, perhaps, reasonably suppose that the greater abruptness of the northern glaciers is due in some measure to the more rapid melting of the drift-

[1] Journal of Geology, 3, 875-902.

laden basal layers of the ice, in consequence, as already explained, of the low specific heat of the imbedded *débris*, and that, possibly, the northern glaciers are more generally drift-laden because the severe climate tends to prevent basal melting. Certain it is that the englacial drift is, in general, most in evidence where the basal conditions most closely approximate those of an ice-sheet in its prime.

It appears to me, however, extremely improbable that all the englacial drift of the Greenland glaciers has been absorbed by the ice during its comparatively short and steep descent from the margin of the ice-cap. I would suggest instead that a considerable part of it represents the lower, drift-laden portion of the ice-cap itself. Whether these lobes of the ice-cap are well charged with drift or not is of no special significance in a study of the Pleistocene ice-sheet of North America, unless we can regard them as reliable indications in this respect of the constitution of the parent ice-cap. Assuming with Chamberlin that, while the upper, clear ice of the Greenland glaciers increases rapidly in thickness from the lower end upward toward the ice-cap, the basal, drift-laden ice increases but little if any in thickness, is it a necessary conclusion that in the ice-cap itself, thousands of feet in thickness, the englacial drift is limited to the lower 100 to 200 feet? To answer in the affirmative is to lose sight of the principle that the velocity of the ice increases rapidly upward from the bottom. The ice-cap virtually spills over the edge of the plateau through deep V-shaped notches; and to my mind the conclusion is unavoidable that a much larger proportion of the upper, clear, and relatively mobile ice will flow down than of the lower, drift-laden, and relatively immobile ice. It is probable that increased declivity would in any case accelerate the velocity of the upper more than of the lower layers of ice, but this contrast would certainly be greatly intensified by the section of the valley — broad and open above, and narrow below.

It is the general belief of geologists that if Greenland were divested of its ice-cap it would exhibit continental relief — elevated margins and a depressed interior. Hence we may assume that the ice-cap attains its maximum thickness in the central areas, and that a smothered mountain range separates this main body of ice from the overflow fringe of glaciers along the coast. The futility of regarding these smaller coastal glaciers as representative, in the matter of englacial drift, of the great ice-cap from the marginal and superficial portions of which they originate is obvious.

The Humboldt glacier and others of the great glaciers of the Greenland coast belong in quite a different category, occupying as they do, apparently, the lower courses and mouths of the great interior valleys; but, terminating in the sea, we can only judge of their basal conditions by the icebergs to which they give rise. It is, perhaps, fair to assume that, through basal melting, these giant glaciers, like their smaller brothers which fail to reach the sea, are building platforms of the ground moraine beneath their extremities and thus permanently shallowing or filling up the bays along the coast. But that the icebergs often carry away generous loads of drift is well known, and we may specially note in this connection (1) that perhaps many of what pass for small bergs are really large bergs deeply laden; (2) that bergs well ballasted with drift cannot possibly be overturned so as to expose the drift to observation; and (3) that the drift-bearing part of a berg, under the combined influence of the higher specific heat of rocky *débris* and gravitation, must melt away very rapidly when the temperature of the water is above freezing. Again, these giant glaciers are simply ice rivers draining at lower levels the great *mer de glace* or interior sea of ice; and, just as in the case of the water of a lake and its outlet stream, the velocity of the ice must be greatly accelerated in passing from the *mer de glace* to the glacier. From this premise the conclusion follows irresistibly, as previously noted, that the glacier will consist in much larger proportion than the *mer de glace* of the upper, drift-free ice. Hence we can hardly suppose that even a clearly exposed section of the Humboldt glacier would reveal to us a true and undistorted vertical section of the Greenland ice-cap, for the basal layers certainly would not be adequately represented. Thus observation is baffled at every point, unless, indeed, a boring should some time be made in the interior of Greenland. I see no reason, however, to doubt that the *mer de glace* is well supplied with englacial drift, or that wherever the ice is actively abrading its bed it holds in its mass the entire volume of detritus, moving, full armed and without any intervening shield or ground moraine, over the unprotected bed-rock.

That the englacial drift rises to a great proportional height in the Greenland or any other ice-cap appears to me, however, by no means a necessary conclusion. Probably very little rises to a greater height than 500 feet, or possibly 1,000 feet, even where the thickness of the ice is one to two miles. In fact, none of the suggested processes of

absorption seem competent to diffuse the detritus through any considerable thickness of the ice, or to carry it far above the summits of the obstructions which give rise to the shearing and flexing movements. I conceive it, rather, to be somewhat crowded in the slow-moving basal strata of ice, whence it is early set free by basal melting to form the ground moraine, and to thin out rapidly upward. Among the causes tending especially to check or limit the upward movement of drift in the ice is the progressive increase in the velocity of the ice from the base upward, in obedience to the principle, already noted, that a current tends to force floating bodies from the lines of highest velocity to those of lowest velocity.

It is possible, however, that, as virtually pointed out by Upham,[1] an important exception to this limitation of the range of englacial drift should be made for the case when a later sedentary ice-sheet is overridden by the re-advance of an earlier sheet, the height attained by the englacial drift depending then upon the thickness of the overridden sheet. Again, a mountainous tract lying in the pathway of the ice-sheet may lead to the incorporation of drift at exceptionally high levels. In fact, the Malaspina glacier is a capital example. According to Russell, the drift which mantles the outer margin of this great piedmont glacier covers, even in parts of the area where it is forest-clad, not less than a thousand feet in thickness of ice, and where it is not forest-clad it rises to still greater heights. Russell states that this superglacial drift consists wholly of the lateral and medial moraines of the tributary glaciers descending from the Mount St. Elias range.

"All of the glaciers which feed the great piedmont ice-sheet are above the snow line, and the *débris* they carry only appears at the surface after the ice descends to the region where the annual waste is in excess of the annual supply. The stones and dirt previously contained in the glacier are then concentrated at the surface, owing to the melting of the ice. This is the history of all the moraines on the glacier. They are formed of the *débris* brought out of the mountains by the tributary Alpine glaciers and concentrated at the surface by reason of the melting of the ice."

Probably this incorporation of drift at high levels would still occur, but on a grander scale, if the St. Elias range were completely buried in ice moving across it. Regarding these St. Elias glaciers as rivers

[1] Bull. Geol. Soc. Amer., 7, 21, 22.

of ice tributary to a sea of ice, the thought is naturally suggested that perhaps the drift-laden ice tends, on joining the piedmont glacier, to flow out across the ice sea regardless of its depth, and thus, while actually descending topographically, rise to greater heights in the ice-sheet. This principle would also, obviously, find application in the case of valleys or depressed areas of any form transverse to the general direction of flow of the ice-sheet, and it thus becomes simply a broader phase of the principle of the absorption of detritus by shearing and flexing. These considerations lead me to venture the opinion that, while depths of englacial drift amounting to 1,500 or 2,000 feet or more, or to one fourth to one third of the thickness of the ice-sheet at its maximum, as held by Upham, cannot be regarded as strictly normal or as prevailing over considerable areas of plain country, they are possible under the special conditions indicated.

Relations of Englacial Drift to Modified Drift.

The manifold forms of modified drift, or washed and stratified gravels, sands, and clays, of glacial origin, forming deltas, terraces, overwash or apron plains, eskers, kames, etc., although occurring almost wholly in valleys and on lowlands, constitute in the aggregate a considerable fraction of the total volume of the drift. Concerning the source of the modified drift, there is as yet no general agreement among glacialists. The main views, of which all others may be regarded as modifications, are (1) that the modified drift has resulted chiefly from the washing and assorting of the till or ground moraine by glacial streams during and following the waning and disappearance of the ice-sheet, (2) that it was derived from englacial drift through the agency of subglacial streams, and (3) that it had its origin in englacial drift which became superglacial by ablation and was washed and assorted by superglacial streams. Undoubtedly all of these theories are required to account for the totality of the modified drift, and the real question is as to their relative importance.

It is inconceivable that the ice-sheet could disappear without some washing or modification of the ground moraine. It is, however, a noteworthy fact that the till does not present about the heads of southward sloping valleys or elsewhere evidences of such extensive erosion as should be required for the general or unqualified accept-

ance of this view. The absence, as a rule, of strongly marked erosion lines in the ground moraine is particularly striking in the case of the drumlins, since their highly definite and characteristic contours due to glacial molding make them extremely delicate records of aqueous erosion. Every glacialist knows how rare and insignificant are the evidences of drumlin erosion which can be referred to subglacial streams. Superglacial and marginal streams have here and there notched the summits or terraced the sides of protruding drumlins, and frost and rain-wash doubtless accomplished some degradation of the drumlins after the disappearance of the ice and before the mat of vegetation was spread over them. But when all these modes of erosion are taken into account, the waste which drumlins have suffered still appears so trifling that, if they were regarded as representative in this respect of the ground moraine in general, all subglacial material might, perhaps, be safely neglected as a source of modified drift. In fact, the advocates of the derivation of the modified drift from the ground moraine should, it would seem, also espouse the theory that drumlins are mere erosion remnants of a sheet of till of much greater average thickness than that which now encumbers the glaciated area.

It may be noted, however, that, as I have elsewhere pointed out,[1] the ice-sheet was probably accompanied, at least in its later stages, by a more or less complete system of subglacial drainage; and during all the time while the ground moraine or subglacial till was accumulating through basal melting, and also while it was still englacial, through the agency of numberless shearing planes, it was undergoing modification by the washing out of its finer constituents, clay and rock flour. Obviously, of this differential erosion no distinct trace or scar could be expected to survive the disappearance of the ice-sheet, especially since the action could not have been sharply localized, but must have affected in some degree almost the entire area of the ground moraine.

While not denying or doubting that the ground moraine has made, in various ways, substantial contributions to the modified drift, I recognize that the relations of the still englacial drift to glacial drainage afford a more direct and satisfactory explanation of the main part of the modified drift.

The real problem appears, then, to be as to the relative efficiency of subglacial and superglacial streams. Upham, the foremost advocate

[1] Proc. Boston Society of Natural History, 25, 117.

of the efficiency and sufficiency of superglacial streams, holds that the englacial drift became superglacial, by surface ablation of the ice, in sufficient volume to account for practically all the various types of modified drift, and that the superglacial streams were adequate for its transportation and deposition. That this must be the history of a part of the modified drift is obvious from the fact that these conditions are realized in modern ice-sheets, but they are only realized, it must be added, to a very limited extent.

It is a common and, perhaps, a fair assumption that in Greenland and Alaska are exhibited now, on a smaller scale, nearly all the essential phases of the disappearance of the Pleistocene ice sheet. A general survey of these and other regions now undergoing glaciation has revealed only one notable occurrence of superglacial drift, namely, that mantling the outer margin of the Malaspina glacier; and that, as we have noted, is of somewhat exceptional origin, inasmuch as it is not derived from strictly normal englacial drift. Little more can be said for superglacial streams. They are either entirely wanting or they are short-lived, being almost invariably swallowed up by crevasses and rarely discharging over the margins of the ice-sheets. Nowhere, so far as I am aware, have superglacial streams been observed actively washing and distributing superglacial drift. Assuming, as I think we must, that the englacial drift is crowded in the basal layers of the ice, enormous wastage of the ice must occur before it becomes superglacial; and the extreme brittleness and consequent fissuring of the ice protect it from the ravages of superglacial streams, until in the course of time it becomes forest-clad and assumes the character of an ancient soil.

It seems to me very probable, however, that when considerable sections or areas of the Pleistocene ice-sheet were so far wasted as to be absolutely stagnant, and when superglacial drift covered its surface and checked the melting of the ice, the still existing crevasses may have become choked with drift to such an extent as to keep the streams superglacial or in channels open to the sky, and thus to realize the essential conditions of the formation of modified drift from superglacial drift. Meanwhile, however, or before these conditions are realized, the water resulting from the melting of thousands of feet of ice has escaped from the ice-sheet through subglacial channels, and during its entire subglacial course the main body of the englacial drift has been within its reach and undergoing modification. This consideration and

the contemplation of the deposits being made at the present time by the Fountain stream, the Yahtse, and other rivers emerging from the base of the Malaspina glacier, not to multiply examples, satisfy me that not only is the modified drift, so far as it is being formed at the present time, the product chiefly of subglacial streams acting on englacial drift, but that it probably was so in Pleistocene times. When it is generally recognized that the modified drift requires not one but several theories, criteria will, doubtless, be established by which we may determine for any normal example whether it has been derived chiefly from subglacial, englacial, or superglacial drift.

The Transportation Argument.

Notwithstanding the abundant and indubitable evidence that a small part of the drift of the Pleistocene ice-sheet is far-traveled, it is generally conceded that the great bulk of the drift is of relatively local origin, and good authorities hold that this is substantially true for the modified drift as well as till. My own studies in the Boston Basin have satisfied me, however, that the modified drift and till of this region are somewhat contrasted in this respect, though perhaps not more than we should expect, considering that the modified drift was transported by water as well as by ice. For example, with the aid of several students in the Massachusetts Institute of Technology, I examined the composition of a prominent esker on the northwest shore of Weymouth. North of this point in the line of glacial movement are three broad belts of rocks: First, slates and conglomerates of the Boston Basin (Carboniferous), about thirteen miles; second, hornblendic granites, diorite and felsite, with some Cambrian slate and quartzite, eight to ten miles; third, mica schists, muscovite granites and gneiss, pegmatite, etc., extending into New Hampshire. We found, on looking over some tons of material, that of all which was coarse enough for easy identification about 50 per cent. is from the first belt, 40 per cent. from the second, and 10 per cent. from the third. Subsequently, at points only two to five miles from the northern edge of the Boston Basin, I found the proportion of material from the first belt in the modified drift very small, 10 per cent or less. Hence it is probably safe to assume that more than half of the coarser material of the modified drift of the Boston Basin is five to ten miles from its source and a good fraction as much as twenty miles.

But conceding that the readily identifiable constituents of the drift,

whether modified or unmodified, are chiefly of distinctly local origin, it may still be doubted whether much weight should be attached to this fact as an argument against the view that practically the entire volume of the drift was englacial in the earlier and maximum stages of the ice-sheet. For the purpose of this discussion the drift may be divided into three parts: First, the preglacial detritus, which must have been chiefly of a residuary and clayey character and highly oxidized (red and yellow), like the residuary soils of the South; second, the finer products of glacial erosion, rock flour, etc., formed chiefly on stoss slopes and for the most part unoxidized; third, the coarser part of the drift, the identifiable rock fragments, which must be almost wholly of glacial origin and derived chiefly from the lee slopes.

The preglacial residuary and sedentary soil was probably partly swept away by aqueous erosion during the elevation of the continent and before the formation of the ice-sheet. What was left of it probably became incorporated with the ice-sheet in its earliest stage; and we may well suppose that during the various vicissitudes of the ice-sheet, and through the coöperation or alternation of glacial, lacustrine, and fluvial transportation, it has been carried in large part beyond the limits of the glaciated area. Certainly there is little indication of its presence in the composition of the drift; and experiment shows that an admixture of a very small proportion of highly oxidized residuary clay, like that of the South, with a typical till is readily detected in the change of color. It is a natural suggestion, therefore, that the Lafayette and Columbian formations of the South have been derived, along their northern borders, in part from the preglacial residuary soils of the North. The finely comminuted and unoxidized glacial detritus constitutes now the basis or matrix of the till, and is very largely represented in the modified drift. But except to a very limited extent it is entirely unidentifiable as to its source and the distance of its transportation. The vast deposits of modified drift in Southeastern New England, and the great average thickness of till in Ohio and other interior States, not to mention distinctly morainal accumulations, indicate, however, when compared with the scanty deposits of drift over many northern areas in New England and Canada, that a large volume of the older, finer, and less readily identifiable part of the drift is relatively far-traveled. In its earliest stages the ice-sheet, we may reasonably suppose, wore away and absorbed a considerable thickness of rotten rock underlying the residuary soil; and during its max-

imum stage, as already noted, the hard rocks suffered glacial abrasion on the lee slopes as well as on the stoss slopes. The conditions must then have been very unfavorable to the rending of the ledges and the detachment of fragments and bowlders; but this came later with the decline of the ice-sheet, when the flowage pressure so far predominated over the vertical pressure that the ice pulled away from instead of following down the lee slopes.

Approaching the subject in this way, I can see no escape from the conclusion that the rock fragments and bowlders must date chiefly from the later stages of the ice-sheet. Hence they must have been, in general, the last material to be absorbed by the ice-sheet and the first to be deposited by basal melting. Under favorable conditions of flexing or shearing a small part of this material attained a high level in the ice and enjoyed a long glacial transport; but the fact that most of it is still near the parent ledges will, I judge, be found quite consistent with the englacial theory if due allowance be made for the relatively short time that it was inclosed in the ice and for its basal position and the low velocity of the basal layers of the ice. Although the total forward movement of the ice, as indicated by far-traveled erratics, appears to have been as much as five or six hundred miles, and even in some parts of the glaciated areas perhaps a thousand miles, a basal slipping of one twentieth of that distance or less would probably be regarded as sufficient to account for the erosion of the bed-rock surface and the normal distribution of the identifiable fragments. In this connection I venture to repeat the suggestion that possibly the total movement of the ice has been overestimated, the more distant erratics having been, perhaps, transported in part by water, and not wholly by the ice-sheet, each marked recession of the ice-sheet providing a series of glacial lakes and rivers along its margin.

Since writing out this paper I have realized more distinctly than before that the points relating to the entire volume of the drift having been englacial during the active erosion of the bed-rock, the efficient protection afforded glaciated surfaces by even a thin layer of till, and the consequent ruling out of drag as a mode of glacial transportation have been previously stated by Mr. Upham.[1] But since I have approached the subject in quite a different way, and there are still minor points of difference, this general acknowledgment is, perhaps, preferable to any attempt at quotation.

[1] Bull. Geol. Soc. Amer., 5, 71–86, etc.

SOME EXPERIMENTS ON THE GROWTH OF DIATOMS.

By GEORGE C. WHIPPLE, S.B.

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In a paper published in 1894 the writer suggested an explanation for the peculiar seasonal distribution of diatoms in lakes and ponds. It was shown that in deep ponds these minute plants are found abundantly during the spring and fall, but are almost entirely absent during the summer and winter; that these growths are closely connected with the phenomena of circulation and stagnation of the water, which phenomena are due to temperature changes; and that it is during the periods of the year when the water is in complete circulation throughout the vertical that the diatom growths occur. The explanation offered for these facts had reference chiefly to the food supply. It was stated that diatoms require a sufficient supply of nitrogen in the form of nitrates, and that they require a free circulation of air; and it was shown how during the "periods of circulation" in the spring and fall these conditions were fulfilled. In the light of more extended observations and experiments this food supply theory, taken alone, is seen to be inadequate, and while it is true that the question of food is one of fundamental importance, yet there are other factors which materially influence their growth. With a view to determining the nature and effect of some of these influences the writer has conducted during the past year several series of experiments, some of the results of which are here presented.

It is not an easy matter to cultivate diatoms successfully in the laboratory to obtain comparative results. They are organisms which have an extremely sensitive nature, and slight changes in their environment often make great differences in their growth. The temperature, the amount of light, the shape and size of the jar in which they are grown, the action of the glass upon the water, etc., are all disturbing elements affecting their growth. Take, for example, the shape of the jar. On one occasion three portions of a sample of

Cochituate water were placed in three jars of various shapes, each of which held 500 cc. In the first the water had a depth of 25 cm. and a surface area of 20 sq. cm.; in the second the depth was 7.1 cm. and the area 70 sq. cm.; in the third the depth was 2.7 cm. and the area 186 sq. cm. The three jars were placed side by side on the window sill so that they received practically the same amount of light, and the temperature was found by observation to be the same in each case. The water in each jar originally contained 226 diatoms per cc. After standing ten days the water in the first jar contained 685 per cc.; in the second jar, 1,537; and in the third jar, 7,585. Of the last 6,060 were Synedra, 1,080 Melosira, 235 Tabellaria, 200 Asterionella, 10 Stephanodiscus. The large number per cc. in the third jar was no doubt partly caused by greater evaporation from the large surface exposed and the consequent higher concentration of the organisms, but it was chiefly due to the greater opportunity for the absorption of air. In the deep jar the water could not take up the oxygen and carbonic acid from the air as fast as the diatoms used them up. Moreover the diatoms settled to the bottom of the jars, where they grew as a brown, velvety layer. The distance of these growths from the surface also affected their supply of air.

Another experiment made at the same time gave similar results. Into three cylinders, equal in diameter, were poured different quantities of the same sample of water. The first contained 100 cc., the second 200 cc., and the third 500 cc., the depths being, respectively, 1.4 cm., 2.9 cm., and 7.1 cm. The original water contained 226 diatoms per cc. After ten days the first jar contained 2,288, the second 1,733, and the third 1,537 per cc.

To more clearly illustrate the fact that diatoms do not grow without air two cultures of reservoir water were made in flasks, one being open to the air and the other covered with a thin layer of oil. The water originally contained 150 per cc. After twenty-five days the open flask contained 7,648 per cc., while the other contained but 192. An attempt to force a growth of diatoms in a flask by allowing air to continually bubble up through the water was a failure, the agitation produced being more than the delicate plants could stand.

It was also found in the laboratory experiments that the position of the jars in the window caused marked variations in the intensity of the growths. Those on the side of the window where the light was strongest gave the heaviest growths, except in one spot where

the sunlight fell; there the growth was small. These facts led to a more extensive investigation to determine the effect of light of varying intensities. It was known, of course, that, in common with all chlorophyllaceous plants, diatoms will not grow in the dark, and it was also known that exposure to bright sunlight will kill them, but between the bright sunlight and total darkness there was a wide field for experiment.

A variety of preliminary experiments was made to determine the best method of regulating the intensity of the light and of securing such conditions that the results would be fairly comparable. They all showed that in the laboratory it was next to impossible to secure the desired result. It was therefore decided to make the experiments in the ponds themselves, under conditions as nearly as possible like those found in nature.

The method employed was an extremely simple one. It consisted of suspending bottles filled with water from the same source at different depths in the pond, the bottles being tied to a rope which hung from an anchored buoy. After a certain time the bottles were drawn to the surface and the water examined, records being kept of the number of diatoms in each sample before and after exposure. The bottles varied in capacity from 150 to 1,000 cc. In the first five experiments they were tightly stoppered, but in the later ones silk bolting cloth was tied over the mouths of the bottles, and inverted glass tumblers were placed above. The latter arrangement gave much heavier growths on account of providing better opportunity for the circulation of air and for the renewal of food supply.

The results of the experiments are given in tabular form at the end of this paper. Before discussing them, however, it will be appropriate to consider the subject of the nature and intensity of the light at various depths in the water.

This subject has not been as thoroughly investigated as its importance appears to demand, and most of the investigations that have been made were made upon the clear water of the ocean or of large lakes. Perhaps the most complete study of the transparency of water was that made by Professor F. A. Forel upon the water of Lake Leman in Switzerland.

His experiments are fully described in the second volume of his recent monograph, entitled *Le Léman.*[1] Three methods of ex-

[1] Forel, F. A. Le Léman, monographie limnologique, Lausanne, 1895.

periment were employed. The first was that of the visibility of plates. This method, first used by Secchi in 1865 in determining the transparency of the water of the Mediterranean Sea, consisted of lowering a white disk (20 cm. in diameter) into the water and noting the depth at which it disappeared from view, and then raising it and noting the point at which it reappeared. The mean of these two depths was called the limit of visibility. The second method, known as that of the Genevan Commission, was similar to the first, but instead of a white disk an incandescent light was lowered into the water. This light when seen through the water from above presented an appearance similar to that of a street lamp in a fog, that is, there was a bright spot surrounded by a halo of diffused light. When the light was lowered into the water this bright spot first disappeared from view. The depth of this point was noted as the "limit of clear vision." Finally the diffused light disappeared, and the depth of this point was noted as the "limit of diffused light." Both the first and second methods were useful only in comparing the relative transparency of different waters or of the same water at different times. In order to get an idea of the intensity of light at different depths a photographic method was used. Sheets of sensitized albumen paper were prepared and mounted in a frame in such a way that half of the sheet was covered with a black screen, while the other half was exposed. A series of these papers was attached to a rope and lowered into the water; they were at equal distances apart, and so supported that they assumed a horizontal position in the water. They were placed in position during the night and allowed to remain twenty-four hours. On the next night they were drawn up and placed in a toning bath. A comparison of the prints made at different depths enabled the observer to determine the depth at which the light ceased to affect the plates and to obtain some idea of the relative intensity of the light at the different depths. To assist in this comparison an arbitrary scale was made by exposing sheets of the same paper to bright sunlight for different lengths of time.

The results of the experiments are given by Forel as follows:

In Lake Leman the limit of visibility of a white disk 20 cm. in diameter was 21 m. The limit of clear vision of a 7-candle-power incandescent lamp was 40 m.; the limit of diffused light was about 90 m. The depth at which the light ceased to have any effect on

the photographic paper was 100 m. when the paper was sensitized with chloride of silver, and about 200 when sensitized with iodobromide of silver. These depths were much less in summer than in winter on account of the increased turbidity of the water. The transparency of the water of other lakes, as shown by the limit of visibility of a white disk, is cited as follows: Lake Tahoe, 33 m.; La Mer des Antilles, 50 m.; Lac Lucal, 60 m.; Mediterranean Sea, 42.5 m.; Pacific Ocean, 59 m. It should be remembered that these are all comparatively light-colored waters, and that in them the light penetrates to far greater distances than in the brown-colored and more or less turbid water of many of our New England ponds. For example, in the Chestnut Hill Reservoir a plate lowered into the water at a time when the color was 0.92 disappeared from view at a depth of only 6 feet.[1]

The decrease in the intensity of light below the surface is due to two causes: First, the absorption of a certain portion of the light by the water; and second, the presence of fine particles in suspension, which act as a screen to shut out the light. The coefficient of absorption of light by water is practically unknown. It varies greatly, of course, with the quality of the water. Wild[2] gives the following figures for distilled water, and shows that the power of absorption increases with the temperature:

Temperature.	Intensity of light after passing through 1 dm. of distilled water.[3]
24.4° Cent.	0.9179
17.0° "	0.93968
6.2° "	0.94769

[1] Recent experiments by the writer have shown that the limit of visibility may be determined most accurately by using a disk about 8 inches in diameter, divided into quadrants painted alternately black and white, like the target of a level rod, and looking vertically down upon it through a water telescope provided with a suitable sun-shade. It has been found that the limit of visibility obtained in this manner bears a very close relation to the turbidity of the water, and it seems quite possible that this simple experiment may be of considerable value in determining the relative turbidities of different waters.

[2] Wild, H. "Ueber die Lichtabsorption der Luft," Poggendorfs Annalen, Anhang, cxxxiv, 582, Berlin, 1868.

[3] Forel considers these values too low, and with this the writer concurs.

The reduction of light in passing through water is supposed to follow the law that as the depth increases arithmetically the intensity of the light decreases geometrically. For example, if the intensity of

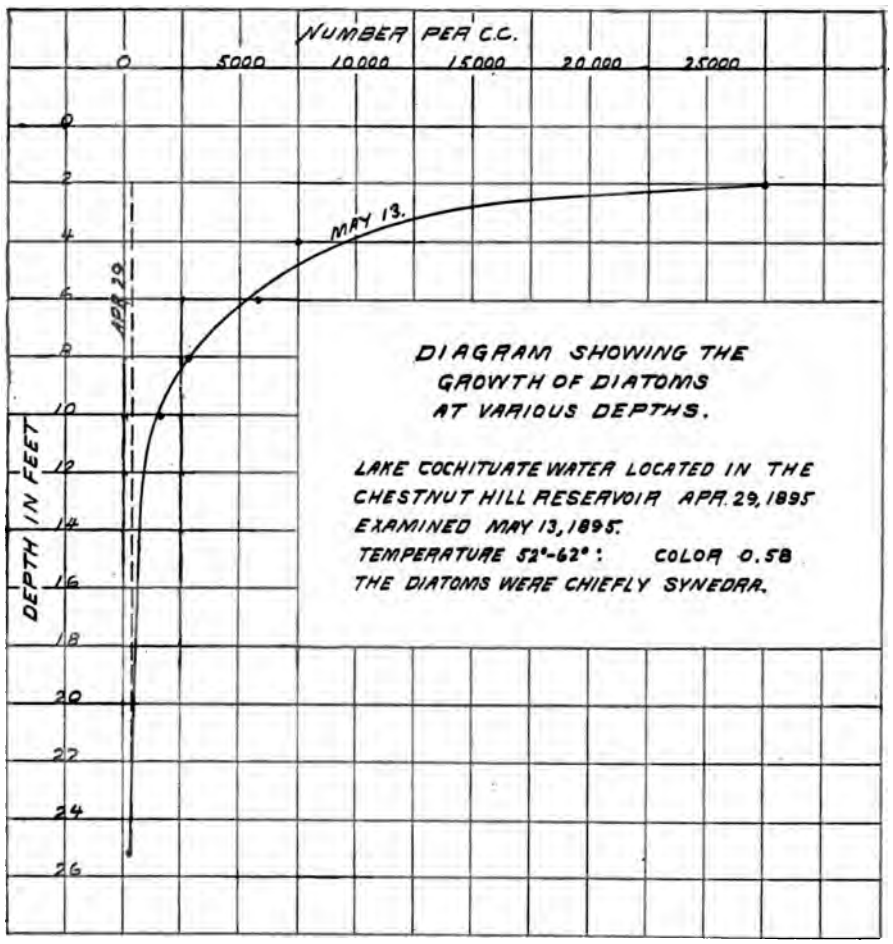


FIG. 1.

the light falling upon the surface of a pond is represented by 1, and if $\frac{1}{4}$ of the light is absorbed by the first foot of water, then the intensity of light at the depth of one foot will be $\frac{3}{4}$; the second foot of water will absorb $\frac{1}{4}$ of $\frac{3}{4}$, and the intensity at a depth of 2 feet

will therefore be $\frac{9}{16}$, and so on. At this rate of decrease the intensity of light at a depth of 10 feet will be only about 5 per cent. of that at the surface.

In regard to the quality of the light at different depths there is little accurate data to be obtained. In a general way, however, it may be said that the red and yellow rays are most readily transmitted.

The practical question to be decided by the experiments was not the exact amount of light necessary for the development of diatoms, but the depth below which they are unable to grow and the difference in the growths at various depths caused by variations in the intensity of the light. The observations here recorded are offered as a partial answer to these questions.

Fig. 1 shows the results of one series of observations. Bottles were filled with Cochituate water and located in Chestnut Hill Reservoir at depths of 2, 4, 6, 8, 10, and 25 feet, where they remained from April 29 to May 13, 1895. During this time the temperature varied from 53° to 62°, and the color of the water in which they were immersed was 0.58 (Platinum Standard). The relative growths at the different depths are shown by the curve, the number of diatoms in the original water being indicated by the broken line. Near the surface, it will be observed, there was a vigorous growth, there being more than 25,000 diatoms per cc. Most of these were Synedra. At greater depths the numbers were less, and at the bottom there were fewer than in the original sample. In Experiments Nos. 3 to 7 the "surface" samples were so placed that at times they were partially above the water, and therefore exposed to varying atmospheric temperatures and occasionally to direct sunlight. The effect was seen in diminished growth. In those series the maximum growth was found just below the surface. In the other experiments the "surface" samples were immersed about 6 inches. These always gave the maximum growths. In Experiment No. 8 there were two "surface" samples—one just above the surface and one immersed 6 inches. The latter gave the greater growth.

At what depth do the diatoms cease to develop, that is, at what depth is the intensity of the light so weak that it is incapable of furnishing the energy sufficient for their growth? The experiments show what we should naturally expect, that it depends upon the character of the water—its color, turbidity, etc. This is illustrated by

Fig. 2, which shows the results of two series of experiments upon water of the same kind located in Lake Cochituate and Chestnut Hill Reservoir. The former had a color of 0.33, while the color of the latter was 0.87. The difference between the two series is very striking. In the light-colored water the growths were heavier and extended to greater depths than in the darker water. Curve No. 1

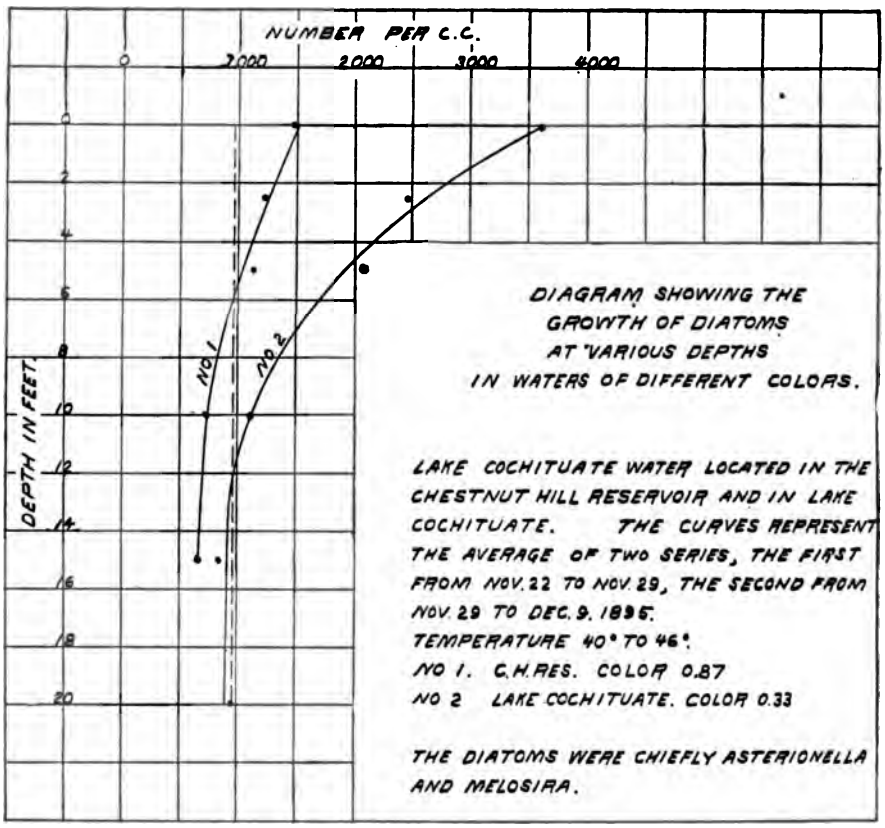


FIG. 2.

represents the growths in Chestnut Hill Reservoir, and Curve No. 2 those in Lake Cochituate. The number of diatoms in the original sample is shown by the broken line. The point at which this broken line cuts the curves may be called the limit of growth. In Lake Cochituate this point was at a depth of about 12 feet; in Chestnut Hill Reservoir, 6 feet.

This limit of growth has been determined for each series of experiments. It varies considerably, but may be shown to be dependent largely upon the color of the water. If, for example, we divide the

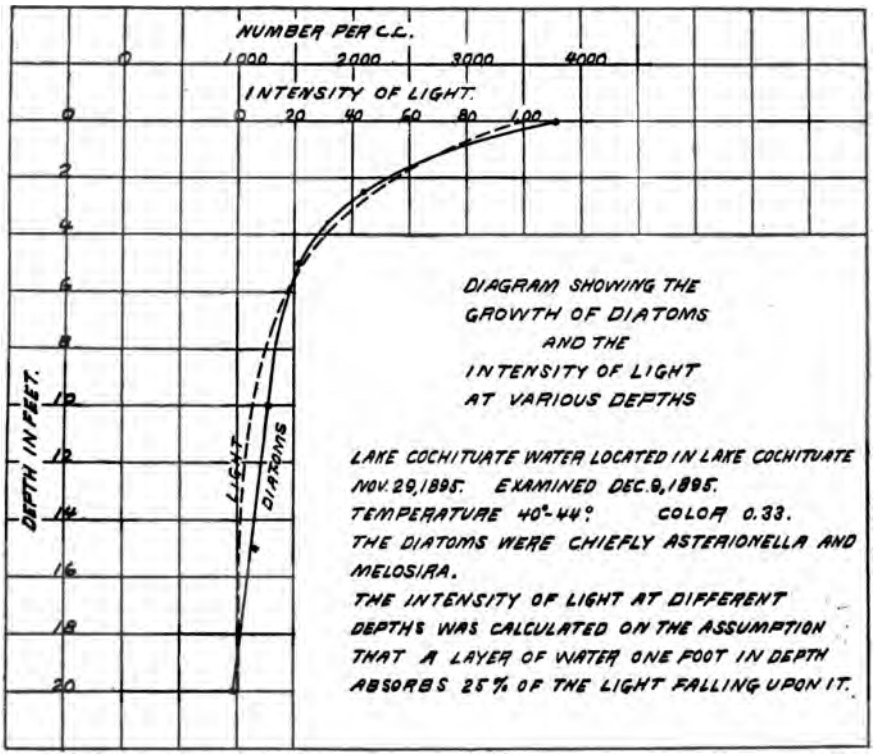


FIG. 3.

experiments into groups according to the color of the water, we obtain the following average values:

Number of Observations.	Average Color. (Platinum Standard.)	Average Limit of Growth in Feet.
5	0.29	15
5	0.60	12
2	0.86	8

Thus we see that in the dark waters the limit of growth is about 8 feet, while in the light waters it is about 15 feet. The limit of

growth in a perfectly clear, colorless water is unknown, but the experiments of Forel and others indicate that it might be found at a considerable depth.

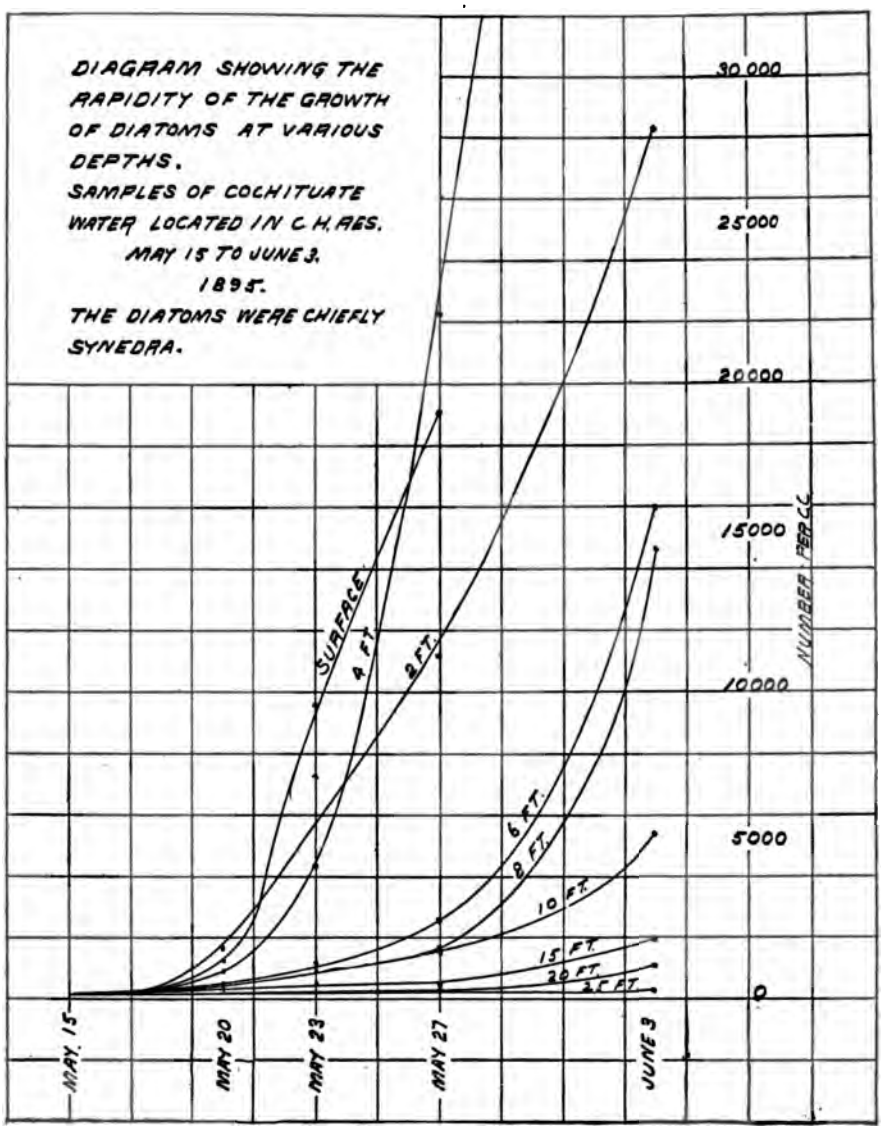


FIG. 4.

In order to appreciate better the fact that the extent of the growth of diatoms depends upon the intensity of the light, let us consider Experiments Nos. 9 and 10. These two series of experi-

ments were made at a time when the temperature of the water in the reservoir was almost exactly the same from the surface to the bottom. The average of the results of these two experiments is shown in Fig. 3. In connection with these experiments the coefficient of absorption of light by the water was approximately determined in the laboratory, and the intensity of light was calculated for the different depths. These values are shown by the broken line in Fig. 3. The parallelism of this line with that representing the growth of diatoms is very striking.

Fig. 4 shows the results of a series of experiments in which several examinations of each sample were made. These emphasize the fact that the rate of growth varies with the amount of light.

In Experiment No. 8 complete microscopical examinations were made. The diatoms, however, were the only organisms that developed extensively. Near the surface a few of the green algæ were seen during the first week or two. The Cyanophyceæ (chiefly a form of Anabæna) increased slightly at first and then began to disappear. Some of the infusoria developed to a slight extent near the surface. Whether this was on account of the difference in the amount of light or in the larger amount of food material near the surface is uncertain. It should be noticed that the amorphous matter increased from week to week, and that it was most abundant near the surface. As a supplement to this experiment, the bottle which had been suspended for three weeks at a depth of 20 feet was brought to the surface on November 30 and supported at a depth of 1 foot. On December 7 the diatoms, which at the bottom had decreased to 149 per cc., were 278 per cc. and in a healthy condition. They would doubtless have increased still more had not the experiment been accidentally terminated.

Diatoms are said to be positively heliotropic, that is, they tend to move towards the light. In some species this power is quite strong; in others it is less noticeable. For the purpose of determining the heliotropism of the diatoms commonly found in water supplies, samples of water rich in diatoms were placed in brass tubes 3 inches in diameter and 32 inches long, having glass ends. One end was covered with a black cap, and the other end exposed to the light. After varying lengths of exposure, portions of the water were drawn from each end of the tubes and examined microscopically. As an example of the results obtained the following may be quoted. Cochituate

water containing 992 diatoms per cc. was exposed in a tube for twelve hours. At the end of that time the water at the light end of the tube contained 1,438, and that at the dark end only 320. Some of the tubes were inclined, to see if the diatoms would move upwards towards the light; some of them were placed vertically; in others the diatoms were given time to settle before the exposure was made. The experiments showed that most of the common genera tended to move towards the light while settling, but that having once reached the bottom of the tube they remained where they fell. They apparently did not possess the power of moving upwards towards the light — certainly not through any great depth of water. But while they could not rise of their own accord, slight currents of convection caused by varying the temperature of the water sufficed to keep them near the surface.

The inability of certain diatoms to rise towards the light of their own accord was also shown by another experiment. Glass tubes $1\frac{1}{4}$ inches in diameter and 5 feet long, open at the lower end but closed at the top, were suspended in the reservoir at a time when Tabellaria and Stephanodiscus were numerous. The tops of the tubes were level with the surface of the water, and were so arranged that samples could be drawn from the closed ends. After these tubes were allowed to stand for a few hours it was almost invariably found that the diatoms had settled and that the water at the top of the tubes was practically free from them. Other experiments along this line are in progress, and it is hoped that some interesting results will be reached.

The bearing which these facts have upon the seasonal distribution of diatoms is obvious, and we are now better able to understand why it is that their growths occur during those seasons of the year when the water is in circulation throughout the vertical. During those periods not only is food more abundant, but the vertical currents keep the diatoms near the surface, where there is light enough to stimulate their growth, and where there is an abundance of air. If this theory be true, it must follow that the weather has a marked influence upon their growth. We should expect that the greatest growths would occur on warm, fair days, when there is just wind enough to keep the diatoms near the surface. On quiet days we should expect that they would sink in the water, perhaps below the limit of their growth. During a long period of quiet weather they might sink even to such a depth that they would not again be able to reach the surface.

This is just what took place in Lake Cochituate in the spring of 1895. In this lake there is almost invariably a heavy spring growth of diatoms, but in 1895 the growth was small. It began as usual,

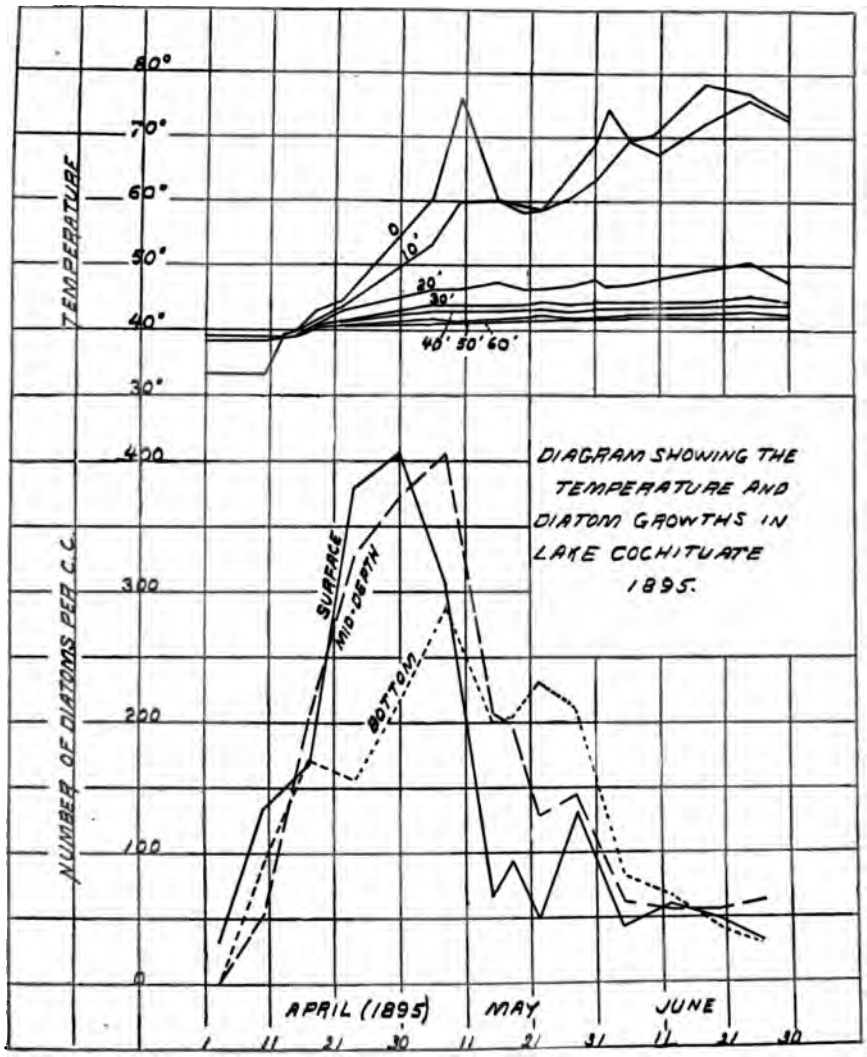


FIG. 5.

the diatoms being apparently in good condition. Early in May, however, there were a few days of uncommonly warm weather. The temperature of the air went above 90°, and the temperature of the

surface water on one day was 76°. For almost a week the water was very calm. During this calm weather the diatoms settled rapidly, disappearing almost entirely from the surface. In the meantime the water became stratified, on account of the high temperature of the surface layers, and when once more the wind began to blow its influence was felt only 10 or 15 feet below the surface. The diatoms, having settled below that depth, were unable to rise, and consequently their growth ceased. These facts are illustrated in Fig. 5. In Basin III, which is not nearly as deep as Lake Cochituate, the growth of diatoms was arrested during the same warm, quiet period, but inasmuch as circulation afterwards reached to the bottom the growth began again, and continued until the next warm, quiet period, which occurred in June, checked it. In this connection it will be recalled that when the ice forms over a pond the diatom growths usually cease (though several notable exceptions might be mentioned).

Since the growth of diatoms depends upon the intensity of light, and since this is greater in colorless than in dark-colored waters, we may naturally expect to find the most extensive growth in light-colored waters. While it is true that food supply is quite as important as light for the growth of these organisms, yet it is true that to a certain extent the light-colored waters do show the greatest tendency to develop diatom growths.

The writer has recently compared the diatom growths in fifty-seven ponds and reservoirs of Massachusetts, as given in the reports of the State Board of Health. The result of this comparison is shown in the following table. From this we see that most of the heaviest growths occur in the light-colored waters, while in the very dark waters there are few. The table also shows that high chlorine, high hardness, and high nitrogen are favorable to their growth. In other words, an abundant food supply and a light-colored water are among their favorable conditions.

Chemical Analysis. (Parts per 100,000.)		Number of Ponds and Reservoirs in which Diatoms are,—			
		Often above 1,000 per cc.	Occasionally above 1,000 per cc.	Usually between 100 and 500 per cc.	Always below 100 per cc.
Color (Nessler Scale.)	0 to 0.30	12	4	9	4
	0.30 to 0.60	6	2	4	0
	0.60 to 1.00	6	1	5	1
	1.00 to ——	0	1	1	1
Excess of Chlorine	0	4	2	1	2
	.01 to .03	8	1	8	2
	.04 to .25	8	3	10	2
	.25 to —	4	2	0	0
Hardness	0 to 0.5	2	1	3	3
	0.5 to 1.0	7	4	5	2
	1.0 to 2.0	8	0	10	1
	2.0 to —	7	3	1	0
Nitrogen as Albuminoid Ammonia, (In solution.)	0 to .0100	2	0	2	1
	.0100 to .0150	6	1	5	3
	.0150 to .0200	8	6	7	1
	.0200 to ——	8	1	5	1
Nitrogen as Free Ammonia	0 to .0010	3	2	5	3
	.0010 to .0030	6	1	10	2
	.0030 to .0100	8	5	4	1
	.0100 to ——	7	0	0	0
Nitrogen as Nitrates	0 to .0050	3	3	5	6
	.0050 to .0100	11	3	13	0
	.0100 to .0200	6	1	1	0
	.0200 to ——	4	1	0	0

The writer has avoided reference to particular genera, for the reason that the experiments were hardly extensive enough to draw any general conclusions. The fact was noticed, however, that different genera require different amounts of light for their best growth. Melosira, for instance, do not require as much light as Synedra. In Experiment No. 2 Melosira were found growing at a depth of 10 feet. In this connection it is interesting to note that Melosira sink in the water more rapidly than many of the common diatoms. It is very seldom, even during a vigorous growth, that they are found more abundant at the surface than at greater depths. It may be that on account of their tendency to sink in the water they have gradually become adapted to their dark environment, and are able to get along with less light than other diatoms. Asterionella, on the other hand, is slow in settling. Even in quiet weather it is found most abundant at the surface. This genus is known to be slightly motile, and it may be that when supplied with a flood of light its power of heliotropism becomes sufficient to overcome the effect of gravity.

In most ponds where diatoms flourish different genera come and go in a most irregular manner; they develop one after another or they all grow at once; sometimes only one genus appears. As yet no theory has been advanced to account for their erratic succession. It is quite possible, however, that the cause may be found to be connected with their motility, their relative specific gravity, and their sensitiveness to light.

In conclusion the writer desires to express his obligations to Mr. W. F. Murphy and Mr. C. E. Livermore, who have kindly assisted him in the various experiments.

EXPERIMENT NO. 1.

Sudbury Water located in Chestnut Hill Reservoir. April 8–29, 1895.
Temperature, 39–53° F. Color, 0.56.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Navicula.	Total.
April 8	All depths.	8	0	1	1	8	0	18
April 29	1 ft.	110	0	4	1,896	16	0	2,026
April 29	5 ft.	162	0	2	54	132	2	352
April 29	10 ft.	0	0	0	3	0	0	3
April 29	15 ft.	0	0	0	2	0	0	2
April 29	20 ft.	0	0	0	8	0	0	8
April 29	25 ft.	0	12	0	6	0	0	18

EXPERIMENT NO. 2.

Cochituate Water located in the Chestnut Hill Reservoir. April 29 to May 13, 1895.
Temperature, 53°–62°. Color, 0.58.

Date.	Depth.	Number per cc.					
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Total.
April 29	All depths.	94	196	3	11	15	319
May 13	2 ft.	4,040	910	20	22,010	550	27,530
May 13	4 ft.	570	80	10	6,800	120	7,580
May 13	6 ft.	380	650	26	4,510	284	5,850
May 13	8 ft.	650	840	26	1,304	100	2,920
May 13	10 ft.	154	1,380	10	80	0	1,624
May 13	25 ft.	16	132	0	88	28	264

EXPERIMENT NO. 3.

Cochituate Water located in the Chestnut Hill Reservoir. May 15 to June 3, 1895. Temperature, 62°–68°. Color, 0.57.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
May 15	All depths.	61	29	12	17	10	0	129
May 20	Surface.	196	28	12	896	104	0	1,236
"	2 ft.	108	32	20	1,408	56	0	1,624
"	4 "	116	56	36	584	80	0	872
"	6 "	88	20	32	288	28	0	456
"	8 "	56	8	24	136	24	0	248
"	10 "	0	0	36	220	8	0	264
"	15 "	48	24	8	192	28	0	300
"	20 "	16	16	32	204	16	0	284
"	25 "	80	36	20	104	0	0	240
May 23	Surface.	140	0	40	9,340	80	0	9,600
"	2 ft.	80	0	80	6,870	0	220	7,250
"	4 "	572	76	48	3,464	204	0	4,364
"	6 "	176	36	60	1,020	104	0	1,396
"	8 "	256	76	48	500	68	0	948
"	10 "	56	56	16	904	24	0	1,056
"	15 "	60	16	20	376	56	0	528
"	20 "	20	0	0	400	0	0	420
"	25 "	12	20	24	152	8	0	216
May 27	Surface.	200	0	60	18,800	40	0	19,100
"	2 ft.	0	0	0	10,100	80	20	10,200
"	4 "	140	100	60	21,550	290	10	22,150
"	6 "	70	50	90	4,580	90	0	4,880
"	8 "	188	56	40	1,184	160	0	1,628
"	10 "	60	92	8	1,256	64	8	1,488
"	15 "	104	56	16	316	16	4	512
"	20 "	40	32	16	404	0	0	492
"	25 "	0	16	20	96	16	0	148
June 3	Surface.	...	...	..	.....	...	...	.....
"	2 ft.	170	0	0	28.050	40	0	28,260
"	4 "	0	0	0	88,600	40	0	88,640
"	6 "	0	0	20	15,850	110	0	15,980
"	8 "	160	0	30	14,250	170	0	14,630
"	10 "	80	120	50	5,140	0	0	5,390
"	15 "	80	20	10	1,830	0	0	1,940
"	20 "	60	80	20	950	10	0	1,120
"	25 "	50	20	20	70	70	0	230

EXPERIMENT NO. 4.

Cochituate Water (from depth of 30 ft.) located in Lake Cochituate. May 31 to June 7, 1895. Temperature, 64°–70°. Color, 0.29.

Date.	Depth.	Number per cc.					
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Total.
May 31	All depths.	31	62	2	2	7	104
June 7	Surface.	350	0	70	380	0	800
June 7	2½ ft.	120	40	80	11,100	50	11,390
June 7	5 ft.	310	0	40	2,030	160	2,540
June 7	10 ft.	32	0	8	44	28	112
June 7	15 ft.	20	0	8	24	8	60
June 7	20 ft.	48	12	8	12	4	84
June 7	25 ft.	24	0	8	32	12	76
June 7	30 ft.	24	48	8	4	16	100
June 7	40 ft.	56	16	28	4	40	144
June 7	50 ft.	40	48	12	20	28	148
June 7	60 ft.	12	56	12	44	40	164

EXPERIMENT NO. 5.

Sudbury Water located in the Chestnut Hill Reservoir. June 5 to June 19, 1895. Temperature, 67°–72°. Color, 0.57.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
June 5	All depths.	6	0	17	12	72	13	120
June 12	Surface.	120	0	0	520	690	0	1,330
June 12	5 ft.	0	0	0	9,500	100	0	9,600
June 12	10 ft.	32	0	20	980	140	0	1,172
June 12	15 ft.	16	0	8	776	72	0	872
June 12	20 ft.	16	0	16	112	64	0	208
June 12	25 ft.	0	0	20	68	192	0	280
June 19	Surface.	..	..	..	....	...	..	....
June 19	5 ft.	40	0	90	28,000	40	0	28,170
June 19	10 ft.	0	0	30	2,870	60	0	2,960
June 19	15 ft.	200	40	80	210	160	0	690
June 19	20 ft.	0	0	12	268	68	0	348
June 19	25 ft.	12	12	60	120	76	0	280

EXPERIMENT NO. 5A.

Cochituate Water located in the Chestnut Hill Reservoir. June 5 to June 19, 1895. Temperature, 67°–72°. Color, 0.57.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
June 5	All depths.	0	0	27	4	8	10	49
June 12	Surface.	110	0	0	300	760	0	1,170
June 12	5 ft.	0	0	10	1,840	80	0	1,930
June 12	10 ft.	16	0	4	888	28	0	936
June 12	15 ft.	0	0	40	72	0	0	112
June 12	20 ft.	24	0	20	182	24	0	252
June 12	25 ft.	0	0	36	16	4	0	56
June 19	Surface.	..	..	..	....	..	..	....
June 19	5 ft.	0	0	20	16,800	0	0	16,820
June 19	10 ft.	0	0	20	10,550	40	0	10,610
June 19	15 ft.	0	0	40	280	20	0	340
June 19	20 ft.	0	0	40	330	0	0	370
June 19	25 ft.	0	0	90	60	0	0	150

EXPERIMENT NO. 6.

Cochituate Water (from depth of 60 ft.) located in the Chestnut Hill Reservoir. July 11 to July 26, 1895. Temperature, 69°–77°. Color, 0.58.

Date.	Depth.	Number per cc.					
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Total.
July 11	All depths.	2	30	8	4	0	44
July 26	Surface.	0	0	0	328	0	328
July 26	2½ ft.	0	32	0	8	0	40
July 26	5 ft.	0	0	0	4,400	0	4,400
July 26	7½ ft.	0	0	0	1,472	0	1,472
July 26	10 ft.	0	0	0	140	56	196
July 26	12½ ft.	0	72	0	32	12	116
July 26	15 ft.	0	60	0	48	68	176
July 26	17½ ft.	0	0	0	32	24	56
July 26	20 ft.	0	24	0	8	0	32
July 26	25 ft.	0	0	0	12	4	16

EXPERIMENT NO. 7.

Reservoir Water located in Lake Cochituate and Basin 3. August 7 to August 17, 1895. Temperature, 70°–78°. Color: Lake Cochituate, 0.28; Basin 3, 0.68.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Cyclotella.	Total.
August 7	All depths.	0	0	25	0	84	3	112
		Lake Cochituate.						
August 17	Surface.	6	0	0	78	102	0	186
August 17	2½ ft.	0	0	0	72	432	20	524
August 17	5 ft.	0	0	0	82	212	12	306
August 17	7½ ft.	..	..	..	..	...	..	...
August 17	10 ft.	0	0	0	20	184	30	234
August 17	15 ft.	0	0	0	2	50	12	64
August 17	20 ft.	0	0	4	8	56	24	92
August 17	30 ft.	0	0	0	6	46	2	54
		Basin 3.						
August 17	2½ ft.	0	0	18	28	340	26	412
August 17	5 ft.	0	0	0	52	158	46	256
August 17	7½ ft.	0	0	0	12	140	2	154
August 17	10 ft.	0	0	0	8	38	0	46

EXPERIMENT NO. 8.

Cochituate Water located in the Chestnut Hill Reservoir. November 8 to November 30, 1895. Temperature, 40°–45°. Color, 0.83.

Date.	Depth.	Number of Standard Units per cc.						
		Diatomaceæ.	Chlorophyceæ.	Cyanophyceæ.	Fungi.	Infusoria.	Total organisms.	Amorphous.
November 8	All depths.	463	4	487	1	36	991	280
November 12	Above surface.	1,278	30	580	4	27	1,919	376
" "	Surface.	1,564	0	632	16	136	2,348	440
" "	2½ ft.	664	5	532	0	95	1,296	308
" "	5 "	676	17	488	8	20	1,209	344
" "	7½ "	520	0	564	12	8	1,104	324
" "	10 "	475	0	476	0	11	962	448
" "	15 "	527	3	384	0	16	930	284
" "	20 "	437	0	456	0	34	927	240
November 16	Above surface.	1,381	0	355	0	20	1,756	555
" "	Surface.	3,075	0	680	0	117	3,872	685
" "	2½ ft.	1,055	13	265	0	83	1,416	375
" "	5 "	665	13	600	15	14	1,307	295
" "	7½ "	440	20	460	0	7	927	310
" "	10 "	543	15	515	0	67	1,140	375
" "	15 "	375	9	465	0	0	849	270
" "	20 "	514	0	375	10	0	899	280
November 23	Above surface.[1]	1,051	0	0	0	4	1,055	850
" "	Surface.	3,464	0	460	0	0	3,924	860
" "	2½ ft.	859	0	470	0	7	1,336	680
" "	5 "	261	0	240	0	15	516	345
" "	7½ "	103	0	215	0	4	322	310
" "	10 "	65	0	155	0	0	220	190
" "	15 "	....	..	...	..	...	....	...
" "	20 "	130	0	40	0	4	174	255
November 30	Above surface.	....	..	...	..	...	....	...
" "	Surface.	3,681	0	50	0	25	3,756	1,115
" "	2½ ft.	1,043	18	220	0	5	1,286	965
" "	5 "	248	0	110	0	4	362	700
" "	7½ "	259	0	95	0	4	358	710
" "	10 "	168	0	25	0	0	193	600
" "	15 "	....	..	...	..	...	....	....
" "	20 "	149	0	10	0	20	179	460

[1] Sample frozen.

EXPERIMENT NO. 9.

Cochituate Water located in Lake Cochituate and the Chestnut Hill Reservoir.
November 22 to 29, 1895. Temperature, 42°–46°.
Color: Lake Cochituate, .33; Chestnut Hill Reservoir, .90.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
November 22	All depths.	824	244	8	24	8	8	1,116
	Lake Cochituate.							
November 29	Surface.	2,820	675	20	0	0	20	3,535
November 29	2½ ft.	2,540	285	10	0	10	0	2,845
November 29	5 ft.	2,180	290	10	0	50	0	2,530
November 29	7½ ft.	1,485	495	5	50	5	0	2,040
November 29	10 ft.	840	110	0	0	0	5	955
November 29	15 ft.	290	205	15	0	0	10	520
November 29	30 ft.	520	360	10	40	20	0	950
November 29	50 ft.	285	520	10	0	15	5	835
	Chestnut Hill Reservoir.							
November 29	2½ ft.	1,070	125	10	0	10	0	1,215
November 29	5 ft.	770	230	5	0	20	0	1,025
November 29	7½ ft.	840	310	5	0	0	0	1,155
November 29	10 ft.	485	140	10	0	0	0	635
November 29	15 ft.	470	145	25	0	0	0	640

EXPERIMENT NO. 10.

Lake Cochituate Water located in Lake Cochituate and the Chestnut Hill Reservoir.
November 29 to December 9, 1895.
Temperature, 40°–44°. Color: Lake Cochituate, .33; Chestnut Hill Reservoir, .84.

Date.	Depth.	Number per cc.						
		Asterionella.	Melosira.	Stephanodiscus.	Synedra.	Tabellaria.	Miscellaneous.	Total.
November 29	All depths.	625	150	13	17	0	5	810
Lake Cochituate.								
December 9	Surface.	3,010	685	35	60	0	0	3,790
December 9	2½ ft.	1,570	505	25	0	0	0	2,100
December 9	5 ft.	1,240	240	40	20	0	0	1,540
December 9	10 ft.	990	270	0	0	0	0	1,260
December 9	15 ft.	865	260	15	0	20	0	1,160
December 9	20 ft.	680	230	15	0	30	0	955
Chestnut Hill Reservoir.								
December 9	Surface.	895	435	40	60	50	0	1,480
December 9	2½ ft.	1,125	265	20	0	10	0	1,420
December 9	5 ft.	965	260	30	0	0	0	1,255
December 9	10 ft.	510	170	55	10	0	0	745
December 9	15 ft.	110	430	20	60	55	0	675

NOTES ON THE BEST FORM OF CROSS SECTION FOR THE COILS OF A GALVANOMETER.

I. When the Needle Is Indefinitely Short.[1]

By FRANK A. LAWS, S.B.

Received May 11, 1896.

The deduction of the equation of the curve bounding the best form of cross section of the coil of a galvanometer is usually made subject to conditions, which may be stated as follows:

A given length of wire is to be wound into a coil, and the cross section of the coil must be such that with a given *P. D.* between its terminals the axial component of magnetic force at the center is a maximum.

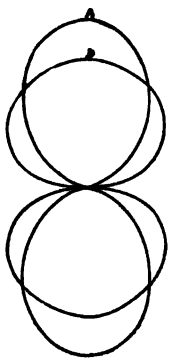
Consider a unit length of wire bent into a circular arc, and let its trace on a plane containing the axis of the coil be defined by the coördinates r and θ, let E be the axial component at center of coil due to the unit length of wire when carrying a unit current, then the equation $r^2 = \frac{I}{E_v} \sin \theta$ gives the locus along which each centimeter of wire will have the same efficacy. This equation is that of the boundary of the best form of cross section, for any transfer of a given length of wire outwards moves it into a position of less efficacy. This is one solution of the general problem; that it is not the only one will appear if the conditions are examined. The solution given is for the case where the resistance of the galvanometer has a determining influence on the current flowing through it. It would, for instance, apply when the instrument is to be used as a current galvanometer under conditions such that the solution for the best galvanometer resistance is applicable, or when the instrument is to be used as a potential galvanometer, for, in order that this instrument may be applicable to any particular piece of work, it must have a resistance above a certain limit, which is fixed by the work in hand. In both cases mentioned, immediately the size of wire is given the problem reduces to the best disposition of a given volume of wire.

[1] The experimental determination of the curves bounding the best form of cross section for the two cases given above, but when the needle is of finite dimensions, is in progress.

A solution corresponding to different conditions may be derived. The problem may be stated thus: Determine the best form of cross section of the coils of a galvanometer when the current through the instrument is independent of its resistance, or, in other words, is controlled by conditions external to the instrument. In order to give definiteness to the problem the area of cross section must be given.

The field at the center of the coil due to one turn, the coördinates of its trace being r, θ is $F = 2\pi c \frac{\sin^2\theta}{r}$, the measure of the efficacy of a turn is $2\pi \frac{\sin^2\theta}{r}$; denote this by E_c, then $r = \frac{2\pi}{E_c} \sin^2\theta$.

Consider that the space within the curve $r = \frac{2\pi}{E_c} \sin^2\theta$ is entirely filled with wire. Any replacement of one of the turns by another outside this area decreases the efficacy of the coil as a whole. That the length of wire may be altered is immaterial, for by the conditions of the problem the current is independent of the resistance of the instrument.



As any replacement of turns by others in space not occupied by the coil diminishes the field at the center of the coil, the form of cross section outlined by the equation $r = \frac{2\pi}{E_c} \sin^2\theta$ is the best under the conditions imposed. This second solution — that for a given cross section — corresponds to the case of the ammeter, for the fundamental principle of ammeter design is that the introduction of the instrument into the circuit shall not alter the current which it is desired to measure.

Above are given the outlines of the cross sections corresponding to both solutions, the areas inclosed by the curves being equal.

The curve A shows the solution when the condition is that of a given cross sectional area, and curve B the solution when the condition is that of a given volume of coil.

ROGERS LABORATORY OF PHYSICS,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
Boston, March, 1896.

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

V.

Received June 12, 1896.

Applied Mechanics.

Tests on Bolted Joints.

The following eight tests form a part of a series not yet finished. This series was planned so as to get an increasing compression per square inch in front of the rivets; the object being to find the effect of this increasing compression on the efficiency of the joint and on the tensile strength of the net section of plate.

All specimens were made from the same sheet of boiler plate, the tensile strength of which was taken from the average of three tests as 68,000 pounds per square inch. The bolts were of machine steel nicely turned. The tensile strength of the bolt steel was 96,300 pounds per square inch, this being the average of three tests. The holes in the plate were drilled and rimmed, and the bolts were fitted so as to be an easy driving fit with a machinist's hammer. The force with which the bolts were set up is noted on some of the tests. Micrometer readings of the stretch of the joints were taken from both the top and the bottom sides, there being two sets of measuring points on each side. The dimensions of the joints are shown in the table following. The accompanying cuts show the joints after fracture.

SUMMARY OF TESTS ON BOLTED JOINTS.

Number of joint.	Size of bolts.	Pitch.	Thickness of plate.	Width of joint.	Area of net section.	Maximum load.	Maximum tension per sq. in. net section.	Maximum shear per sq. in. on bolts.	Maximum compression per sq. in.	Average thickness in front of bolts at fracture.	Reduction of area. (Net section.)	Efficiency.
1	[illegible]″	2″	.43″	6.01″	1.62	102,000	63,100	38,500	105,400	.49″	31%	58%
2	[illegible]″	2″	.43″	6.00″	1.61	101,100	62,600	38,100	104,500	.49″	15%	57%
3	[illegible]″	2 1/8″	.43″	7.69″	2.18	137,000	62,900	38,000	121,000	.51″	28%	61%
4	[illegible]″	2 1/8″	.43″	7.70″	2.18	136,000	62,300	37,700	120,500	.52″	30%	60%
5	1″	3 1/4″	.44″	9.76″	2.97	179,500	60,400	38,100	136,000	.57″	28%	62%
6	1″	3 1/4″	.44″	9.76″	2.97	180,700	60,800	38,300	136,900	.58″	23%	62%
7	1 1/8″	4″	.45″	12.00″	3.88	238,500	61,500	39,900	158,600	.59″	25%	65%
8	1 1/8″	4″	.45″	12.00″	3.88	225,500	58,100	37,600	148,600	.56″	26%	62%

Joint No. 2 broke by shearing.

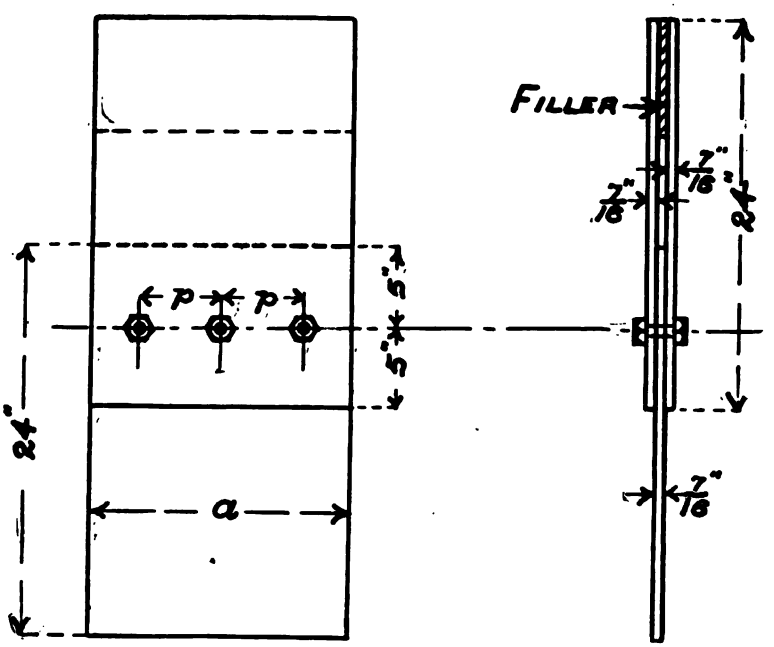


FIG. 1. GENERAL DIMENSIONS OF JOINTS.

Distance between measuring clamps = 12″.

No.	*d*	*p*	*a*
1– 2	3/4″	2″	6″
3– 4	7/8″	2 1/8″	7 11/16″
5– 6	1″	3 1/4″	9 3/4″
7– 8	1 1/8″	4″	12″
9–10	1 1/4″	4 1/16″	14 1/16″
11–12	1 1/8″	5 1/8″	17 1/4″

d = diameter of bolts. *p* = pitch. *a* = width of plate.

FIG. 2. BOLTED JOINT, NO. 1.

TEST ON BOLTED JOINT. No. 1. (FIG. 2.)

Date, November 5, 1895.

Loads.	North Side.				South Side.				North Side.		South Side.		Average difference.	Total difference.
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.		
1,500	.0678	.0675	.0923	.0923	.4723	.4726	5125	.5123	.0500	....	.4924	....	....	....
3,500	.0070	.0672	.0928	.0930	.4720	.4725	.5150	.5152	.0500	.0000	.4937	.0013	.0007	....
5,500	.0080	.0682	.0933	.0931	.4730	.4732	.5155	.5156	.0507	.0007	.4943	.0006	.0007	.0014
6,500	.0083	.0679	.0938	.0936	.4736	.4740	.5163	.5166	.0509	.0002	.4951	.0008	.0005	.0019
Load dropped off for 21 hours; plate strained to 13,500, and load dropped again for 21 hours.														
6,500	.0746	.0748	.1072	.1073	.4863	.4862	.5378	.5378	.0910	....	.5120	....	....	....
9,500	.0759	.0757	.1078	.1076	.4867	.4867	.5383	.5382	.0918	.0008	.5125	.0005	.0007	.0026
12,500	.0762	.0763	.1088	.1088	.4871	.4869	.5383	.5382	.0925	.0009	.5126	.0001	.0005	.0031
18,500	.0768	.0770	.1085	.1083	.4900	.4901	.5395	.5394	.0927	.0002	.5150	0024	.0013	.0044
24,500	.0755	.0753	.1074	.1073	.4950	.4948	.5445	.5443	.0914	—.0013	.5197	.0047	.0017	.0061
27,500	.0772	.0772	.1089	.1090	.4950	.4948	.5444	.5446	.0931	.0017	.5198	.0001	.0009	.0070
30,500	.0786	.0785	.1097	.1098	.4954	.4953	.5450	.5452	.0942	.0011	.5202	.0004	.0008	.0078
33,500	.0790	.0788	.1099	.1111	.4954	.4954	.5461	.5463	.0950	.0008	.5208	.0006	.0007	.0085
Load dropped off for 21 hours.														
33,500	.0800	.0801	.1112	.1113	.4980	.4978	.5483	.5484	.0957	....	.5231	....	....	....
36,500	.0813	.0813	.1120	.1120	.4988	.4990	.5492	.5493	.0967	.0010	.5240	.0009	.0010	.0095
39,500	.0864	.0862	.1168	.1170	.4973	.4973	.5485	.5485	.1016	.0049	.5229	—.0011	.0019	.0114
42,500	.0886	.0884	.1200	.1201	.4976	.4975	.5498	.5500	.1043	.0027	.5237	.0003	.0018	.0132
48,500	.0917	.0917	.1252	.1253	.5015	.5016	.5538	.5540	.1085	.0042	.5277	.0040	.0041	.0173
51,500	.0972	.0973	315	.1313	.5027	.5025	.5573	.5574	.1143	.0058	.5300	.0023	.0041	.0214
54,500	.1080	.1082	.1438	.1440	.5065	.5063	.5625	.5627	.1260	.0117	.5345	.0045	.0081	.0295
Load dropped off for 69 hours.														
54,500	.1058	.1059	.1406	.1408	.5127	.5127	.5653	.5653	.1232	....	.5390	....	....	....
60,500	.1324	.1322	.1683	.1683	.5178	.5179	.5717	.5716	.1503	.0271	.5448	.0058	.0165	.0460
66,500	.1684	.1682	.2048	.2048	.5200	.5200	.5717	.5719	.1866	.0363	.5459	.0011	.0187	.0647
72,500	.2331	.2329	.2690	.2692	.5168	.5168	.5707	.5705	.2511	.0645	.5437	—.0022	.0312	.0959
102,000	Maximum load. (Plate broke by tearing at one side and then shearing bolt on opposite side.)													

Size of bolts	$\frac{7}{8}$"	Maximum tension per sq. in. on net section of plate	63,100 lbs.
Pitch of bolts	2"	Maximum shear per sq. in. on bolt	38,500 lbs.
Thickness of plate	.43"	Maximum compression per sq. in. on plate,	105,400 lbs.
Width of plate	6.01"	Av. thickness of plate in front of bolts at fracture	.49 in.
Area net section of plate	1.62 sq. in.	Reduction of area of net section of plate	31%
		Efficiency of joint	58%

Bolts were set up with 60 lbs. pull on 10-in. wrench.

TEST ON BOLTED JOINT. No. 2. (FIG. 3.)

Date, November 12, 1895.

Loads.	North Side.				South Side.				North Side.		South Side.		Average difference.	Total difference.
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.		
500	.0375	.0375	.1231	.1229	.5729	.5728	.6657	.6658	.0803	....	.6193	....	....	....
5,500	.0352	.0352	.1213	.1211	.5767	.5765	.6700	.6702	.0782	—.0021	.6234	.0041	.0010	.0010
10,500	.0323	.0321	.1195	.1196	.5807	.5805	.6753	.6753	.0759	—.0023	.6280	.0046	.00115	.0022
15,500	.0290	.0290	.1176	.1176	.5852	.5853	.6806	.6806	.0733	—.0026	.6329	.0049	.00115	.0033
20,500	.0269	.0267	.1156	.1156	.5899	.5897	.6855	.6856	.0712	—.0021	.6377	.0048	.00135	.0047
	Load dropped off for 21 hours.													
20,500	.0274	.0272	.1151	.1152	.5917	.5917	.6877	.6876	.0712	....	.6397	....	....	....
25,500	.0240	.0241	.1115	.1113	.5979	.5979	.6939	.6940	.0677	— .0035	.6459	.0062	.0014	.0061
30,500	.0224	.0223	.1108	.1106	.6018	.6019	.6997	.6997	.0665	— .0012	.6508	.0049	.0019	.0080
35,500	.0173	.0173	.1062	.1064	.6117	.6116	.7091	.7092	.0618	— .0047	.6604	.0096	.0025	.0105
40,500	.0065	.0064	.0954	.0953	.6321	.6319	.7298	.7300	.0509	— .0109	.6810	.0206	.0049	.0154
45,500	—.0067	—.0067	.0820	.0818	.6572	.6573	.7546	.7546	.0376	— .0133	.7059	.0250	.0059	.0213
50,500	—.0114	—.0113	.0782	.0782	.6701	.6703	.7689	.7690	.0334	— .0042	.7196	.0137	.0048	.0261
55,500	—.0254	—.0252	.0650	.0652	.7026	.7028	.8030	.8028	.0249	— .0085	.7528	.0332	.0124	.0385
60,500	—.0347	—.0347	.0566	.0566	.7317	.7319	.8322	.8324	.0110	— .0140	.7821	.0293	.0077	.0462
65,500	—.0440	—.0440	.0489	.0489	.7806	.7808	.8820	.8822	.0025	—.00850	.8314	.0494	.0205	.0667
70,500	—.0385	—.0387	.0555	.0554	.8086	.8100	.9109	.9109	.0085	.0050	.8601	.0287	.0169	.0836
101,100	Maximum load. (Bolts sheared in succession, beginning on most strained side.)													

Size of bolts	⅞″	Maximum tension per sq. in. on net section of plate	62,600 lbs.
Pitch of bolts	2″	Maximum shear per sq. in. on bolts	38,100 lbs.
Thickness of plate	.43″	Maximum compression per sq. in. on plate,	104,500 lbs.
Width of plate	6.00″	Av. thickness of plate in front of bolts at fracture	.49 in.
Area net section of plate	1.61 sq. in.	Reduction of area of net section of plate	15%
Bolts were set up with 60 lbs. pull on 10-in. wrench.		Efficiency of joint	57%

FIG. 3. BOLTED JOINT, NO. 2.

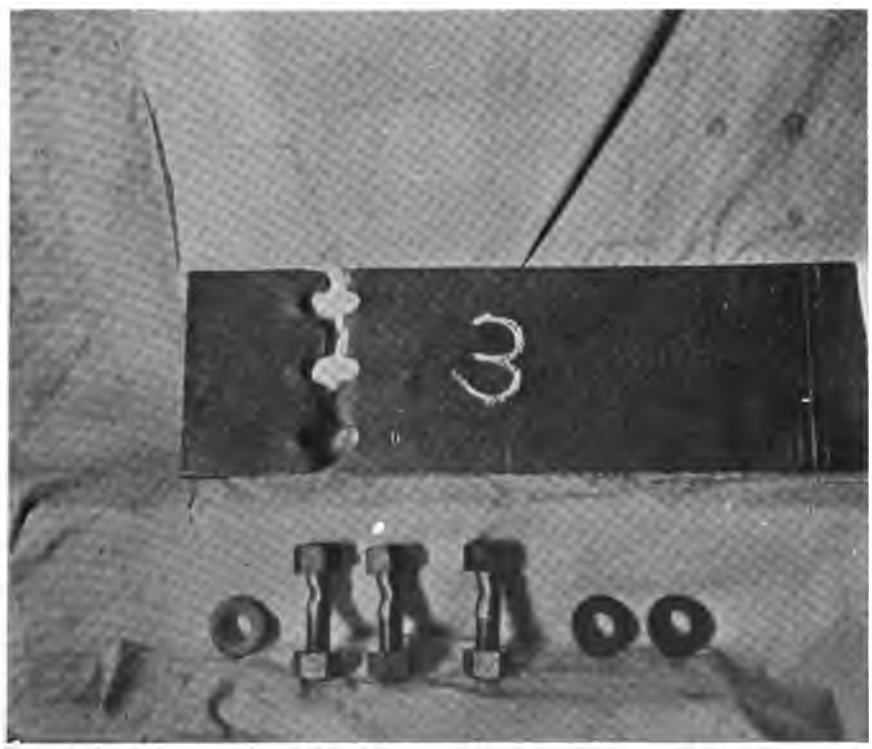


FIG. 4. BOLTED JOINT, NO. 3.

TEST ON BOLTED JOINT. No. 3. (FIG. 4.)

Date, November 14, 1895.

Loads.	North Side.				South Side.				North Side.		South Side.			
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.	Average difference.	Total difference.
500	.5157	.5158	.6168	.6168	.0332	.0333	.1534	.1532	.5663	....	.0933	....	....	....
5,500	.5191	.5193	.6176	.6175	.0335	.0335	.1491	.1490	.5684	.0021	.0913	—.0020	.0001	.0001
10,500	.5193	.5194	.6157	.6157	.0365	.0363	.1503	.1503	.5675	—.0008	.0934	.0021	.0007	.0008
15,500	.5174	.5173	.6140	.6138	.0408	.0408	.1539	.1537	.5657	—.0019	.0973	.0039	.0010	.0018
20,500	.5139	.5138	.6091	.6092	.0460	.0459	.1582	.1580	.5615	—.0042	.1020	.0047	.0003	.0021
25,500	.5134	.5134	.6069	.6069	.0500	.0500	.1615	.1613	.5602	—.0013	.1057	.0037	.0012	.0033
30,500	.5118	.5120	.6061	.6062	.0524	.0522	.1641	.1640	.5591	—.0011	.1082	.0025	.0007	.0040
	Load dropped off for 21 hours.													
30,500	.5120	.5122	.6104	.6104	.0541	.0542	.1654	.1654	.5613	....	.1098	....	....	....
35,500	.5110	.5112	.6079	.6079	.0578	.0579	.1693	.1693	.5595	.0018	.1136	.0038	.0010	.0050
40,500	.5068	.5067	.6030	.6030	.0670	.0678	.1783	.1782	.5549	.0046	.1226	.0090	.0022	.0072
45,500	.4859	.4859	.5820	.5818	.1128	.1128	.2225	.2227	.5339	.0110	.1677	.0451	.0171	.0243
50,500	.4833	.4834	.5784	.5785	.1193	.1192	.2289	.2289	.5309	.0030	.1748	.0071	.0021	.0264
55,500	.4821	.4823	.5780	.5781	.1237	.1238	.2328	.2328	.5301	.0008	.1783	.0035	.0014	.0278
60,500	.4794	.4794	.5741	.5742	.1339	.1332	.2421	.2422	.5268	.0033	.1877	.0094	.0031	.0309
65,500	.4534	.4534	.5474	.5474	.1959	.1958	.3037	.3037	.5004	.0470	.2497	.0620	.0075	.0384
70,500	.4504	.4504	.5447	.5449	.2060	.2058	.3139	.3137	.4975	.0029	.2599	.0102	.0037	.0421
75,500	.4413	.4414	.5360	.5360	.2306	.2305	.3381	.3380	.4887	.0088	.2893	.0294	.0103	.0524
80,500	.4325	.4324	.5261	.5260	.2573	.2575	.3651	.3649	.4798	.0089	.3112	.0219	.0065	.0589
85,500	.4203	.4205	.5140	.5139	.2970	.2972	.4041	.4043	.4672	.0126	.3507	.0395	.0135	.0724
90,500	.4060	.4062	.4992	.4994	.3441	.3442	.4507	.4507	.4527	.0145	.3974	.0467	.0161	.0885
137,000	Maximum load. (Joint gave way by plate tearing.)													

Size of bolts	$\frac{7}{8}$″	Maximum tension per sq. in. on net section of plate	62,900 lbs.
Pitch of bolts	$2\frac{5}{16}$″	Maximum shear per sq. in. on bolts	38,000 lbs.
Thickness of plate	.43″	Maximum compression per sq. in. on plate,	121,000 lbs.
Width of plate	7.69″	Av. thickness of plate in front of bolts at fracture	.51″
Area net section of plate	2.18 sq. in.	Reduction of area of net section of plate	28%
Bolts were set up with 60 lbs. pull on 11-in. wrench.		Efficiency of joint	61%

TEST ON BOLTED JOINT. No. 4. (FIG. 5.)

Date, November 18, 1895.

Load.	North Side.				South Side.				North Side.		South Side.		Average difference.	Total difference.
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.		
500	.2378	.2380	.2867	.2867	.4240	.4239	.4872	.4870	.2623	....	.4555	....	....	....
5,500	.2405	.2403	.2877	.2878	.4240	.4239	.4857	.4858	.2641	.0018	.4548	.0007	.0006	....
10,500	.2426	.2428	.2898	.2897	.4232	.4233	.4834	.4835	.2662	.0021	.4533	.0015	.0003	.0009
15,500	.2413	.2414	.2945	.2943	.4207	.4208	.4844	.4844	.2679	.0017	.4525	.0008	.0013	.0022
20,500	.2423	.2421	.2938	.2939	.4252	.4250	.4880	.4880	.2680	.0001	.4565	.0040	.0022	.0044
25,500	.2425	.2423	.2932	.2931	.4264	.4266	.4894	.4893	.2678	—.0002	.4579	.0014	.0006	.0050
30,500	.2382	.2380	.2930	.2932	.4298	.4297	.4920	.4920	.2656	—.0012	.4609	.0031	.0010	.0060
35,500	.2400	.2401	.2929	.2928	.4328	.4326	.4936	.4934	.2664	.0008	.4631	.0022	.0015	.0075
	Load dropped off for 21 hours.													
35,500	.2392	.2391	.2922	.2922	.4366	.4364	.4936	.4936	.2657	....	.4351	....	....	....
40,500	.2395	.2395	.2928	.2929	.4368	.4366	.4935	.4937	.2662	+.0005	.4652	.0001	.0003	.0078
45,500	.2389	.2391	.2924	.2925	.4391	.4393	.4968	.4968	.2657	—.0005	.4680	.0028	.0012	.0090
50,500	.2398	.2398	.2934	.2932	.4419	.4420	.4990	.4990	.2665	.0008	.4705	.0025	.0017	.0107
55,500	.2393	.2392	.2935	.2936	.4465	.4465	.5053	.5052	.2664	—.0001	.4759	.0054	.0027	.0134
60,500	.2378	.2378	.2922	.2922	.4549	.4548	.5127	.5128	.2650	+.0014	.4838	.0079	.0047	.0181
65,500	.2384	.2384	.2926	.2927	.4607	.4605	.5184	.5185	.2655	.0005	.4895	.0257	.0031	.0212
70,500	.2315	.2316	.2859	.2858	.4944	.4946	.5425	.5425	.2587	—.0068	.5185	.0290	.0111	.0323
75,500	.2307	.2307	.2861	.2861	.5023	.5023	.5802	.5802	.2574	—.0013	.5413	.0228	.0108	.0431
80,500	.2265	.2267	.2816	.2818	.5407	.5409	.6000	.6002	.2541	—.0033	.5705	.0292	.0130	.0561
85,500	.2353	.2353	.2901	.2901	.5641	.5642	.6222	.6223	.2627	.0086	.5933	.0228	.0157	.0718
90,500	.2460	.2461	.3015	.3015	.5930	.5932	.6521	.6519	.2738	.0111	.6226	.0293	.0202	.0920
95,500	.2689	.2689	.3249	.3249	.6148	.6148	.6737	.6736	.2969	.0231	.6442	.0216	.0224	.1144
100,500	.3004	.3005	.3322	.3322	.6392	.6392	.6994	.6994	.3103	.0134	.6693	.0251	.0193	.1337
105,500	.3472	.3472	.4503	.4504	.6653	.6658	.7268	.7271	.3988	.0885	.6963	.0270	.0578	.1915
136,000	Maximum load. (Joint gave way by plate tearing.)													

Size of bolts	$\frac{7}{8}$"	Maximum tension per sq. in. on net section of plate	62,300 lbs.
Pitch of bolts	$2\frac{1}{16}$"	Maximum shear per sq. in. on bolts	37,700 lbs.
Thickness of plate	.43"	Maximum compression per sq. in. on plates,	120,500 lbs.
Width of plate	7.70"	Av. thickness of plate in front of bolts at fracture	.52"
Area net section of plate	2.18 sq. in.	Reduction of area of net section of plate	30%
Bolts were set up with 60 lbs. pull on 11-in. wrench.		Efficiency of joint	60%

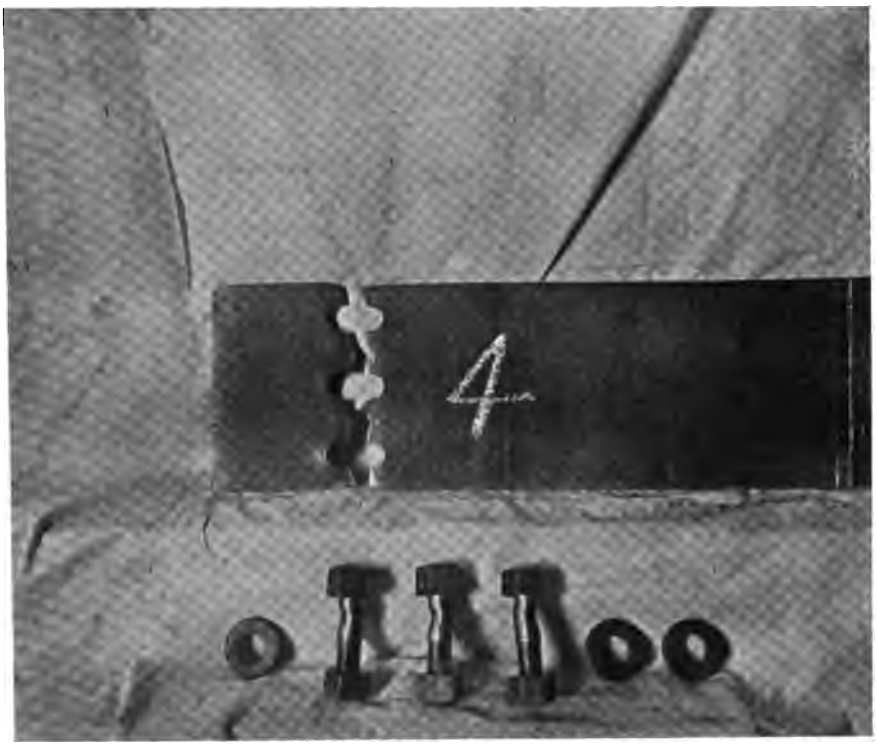


FIG. 5. BOLTED JOINT, NO. 4.

FIG. 6. BOLTED JOINT, NO. 5.

TEST ON BOLTED JOINT. No. 5. (FIG. 6.)

Date, November 22, 1895.

Loads.	North Side.				South Side.				North Side.		South Side.		Average difference.	Total difference.
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.		
500	.0316	.0314	.1576	.1576	.5521	.5520	.6770	.6768	.0945	....	.61447	....	....	....
5,500	.0311	.0311	.1576	.1575	.5541	.5540	.6798	.6799	.0943	—.0002	.61695	.0025	.0012	.0012
10,500	.0319	.0319	.1568	.1569	.5569	.5569	.6811	.6811	.0944	.0001	.61900	.0021	.0011	.0023
15,500	.0321	.0321	.1591	.1590	.5566	.5564	.6839	.6838	.0956	.0012	.62018	.0012	.0012	.0035
20,500	.0330	.0331	.1598	.1599	.5585	.5587	.6852	.6852	.0964	.0008	.62190	.0017	.0013	.0048
25,500	.0394	.0394	.1667	.1669	.5545	.5545	.6811	.6810	.1031	.0067	.61778	—.0041	.0013	.0061
	Load dropped off for 69 hours.													
25,500	.0392	.0393	.1665	.1665	.5546	.5545	.6808	.6808	.1028	....	.6177	....	....	....
30,500	.0413	.0412	.1691	.1692	.5537	.5537	.6808	.6808	.1052	.0024	.6172	—.0005	.0010	.0071
35,500	.0423	.0422	.1709	.1709	.5541	.5542	.6812	.6812	.1066	.0014	.6177	—.0005	.0010	.0081
40,500	.0500	.0499	.1798	.1799	.5508	.5510	.6792	.6791	.1149	.0083	.6150	—.0027	.0028	.0109
45,500	.0526	.0527	.1828	.1828	.5504	.5505	.6789	.6789	.1177	.0028	.6147	—.0003	.0013	.0122
50,500	.0553	.0553	.1857	.1857	.5498	.5498	.6788	.6788	.1205	.0028	.6143	—.0004	.0012	.0134
55,500	.0727	.0729	.2062	.2062	.5409	.5409	.6717	.6719	.1395	.0190	.6064	—.0079	.0056	.0190
60,500	.0809	.0811	.2131	.2131	.5390	.5390	.6703	.6703	.1470	.0075	.6047	—.0017	.0029	.0219
65,500	.0849	.0851	.2188	.2190	.5378	.5378	.6689	.6689	.1519	.0049	.6034	—.0013	.0018	.0237
70,500	.1388	.1387	.2740	.2739	.5157	.5158	.6482	.6482	.2063	.0544	.5820	—.0014	.0165	.0402
75,500	.1568	.1566	.2932	.2933	.5068	.5068	.6403	.6404	.2250	.0187	.5736	—.0084	.0052	.0454
	Load dropped off for 18 hours.													
75,500	.1573	.1572	.2944	.2942	.5058	.5059	.6393	.6394	.2258	....	.5726	....	....	....
80,500	.1598	.1599	.2968	.2968	.5060	.5059	.6396	.6398	.2283	.0025	.5728	.0002	.0013	.0467
85,500	.1992	.1994	.3364	.3366	.4958	.4957	.6298	.6297	.2679	.0396	.5627	—.0101	.0147	.0614
90,500	.2831	.2832	.4222	.4224	.4972	.4972	.6330	.6332	.3527	.0848	.5652	.0025	.0436	.1050
95,500	.2949	.2948	.4343	.4343	.5043	.5042	.6398	.6397	.3646	.0119	.5720	.0068	.0098	.1148
100,500	.2998	.2997	.4392	.4393	.5131	.5131	.6487	.6488	.3695	.0049	.5809	.0089	.0069	.1217
105,500	.3002	.3001	.4399	.4401	.5141	.5140	.6500	.6499	.3701	.0006	.5820	.0011	.0008	.1225
110,500	.3034	.3033	.4426	.4428	.5171	.5172	.6528	.6529	.3730	.0029	.5850	.0030	.0029	.1254
115,500	.3065	.3066	.4664	.4466	.5208	.5207	.6786	.6787	.3765	.0035	.5997	.0147	.0091	.1345
	Load dropped off for 1 hour.													
115,500	.3342	.3340	.4785	.4787	.5468	.5470	.6831	.6832	.4064	....	.6150	....	....	....
120,500	.3359	.3361	.4809	.4809	.5518	.5516	.6891	.6889	.4085	.0021	.6204	.0054	.0038	.1383
125,500	.3604	.3602	.5052	.5050	.5752	.5752	.7116	.7118	.4327	.0242	.6435	.0231	.0237	.1620
130,500	.4064	.4063	.5473	.5472	.6097	.6095	.7462	.7463	.4768	.0441	.6779	.0344	.0785	.2405
179,500	Maximum load.													

Size of bolts	1″	Maximum tension per sq. in. on net section of plate	60,400 lbs.
Pitch of bolts	3¼″	Maximum shear per sq. in. on bolts	38,100 lbs.
Thickness of plate	.44″	Maximum compression per sq. in. on plate,	136,000 lbs.
Width of plate	9.76″	Av. thickness of plate in front of bolts at fracture	.57″
Area net section of plate	2.97 sq. in.	Reduction of area of net section of plate	28%
Bolts were set up with 60 lbs. pull on 12-in. wrench.		Efficiency of joint	62%

TEST ON BOLTED JOINT. No. 6. (FIG. 7.)

Date, December 3, 1895.

Loads.	North Side.				South Side.				North Side.		South Side.		Average difference.	Total difference.
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.		
500	.5631	.5632	.6570	.6568	.0683	.0683	.1732	.1733	.6100	....	.1208	....	....	....
5,500	.5593	.5594	.6607	.6605	.0698	.0698	.1787	.1786	.6100	.0000	.1242	.0034	.0017	.0017
10,500	.5594	.5594	.6570	.6570	.0738	.0736	.1802	.1800	.6082	—.0018	.1269	.0027	.0005	.0022
15,500	.5592	.5593	.6567	.6567	.0761	.0761	.1832	.1834	.6080	—.0002	.1297	.0028	.0013	.0035
20,500	.5592	.5592	.6581	.6582	.0770	.0772	.1850	.1852	.6087	.0007	.1311	.0014	.0011	.0046
25,500	.5607	.5605	.6580	.6582	.0787	.0785	.1860	.1862	.6094	.0007	.1324	.0013	.0010	.0056
30,500	.5617	.5618	.6593	.6594	.0804	.0802	.1878	.1877	.6105	.0011	.1340	.0016	.0014	.0070
35,500	.5612	.5614	.6594	.6592	.0824	.0823	.1898	.1896	.6103	—.0002	.1360	.0020	.0009	.0079
40,500	.5620	.5620	.6590	.6590	.0853	.0851	.1922	.1923	.6105	.0002	.1387	.0027	.0015	.0094
45,500	.5619	.5619	.6598	.6598	.0870	.0869	.1938	.1938	.6109	.0004	.1408	.0021	.0013	.0117
	Load dropped off for 2 hours.													
45,500	.5561	.5562	.6585	.6583	.0901	.0901	.1964	.1965	.6073	....	.1433	....	....	....
50,500	.5549	.5550	.6578	.6578	.0941	.0940	.1992	.1998	.6064	—.0009	.1469	+.0036	.0014	.0131
55,500	.5532	.5532	.6545	.6544	.1029	.1028	.2087	.2085	.6038	—.0026	.1557	.0088	.0031	.0162
60,500	.5514	.5512	.6543	.6545	.1084	.1084	.2147	.2148	.6028	—.0010	.1616	.0059	.0015	.0177
65,500	.5471	.5473	.6514	.6513	.1211	.1211	.2268	.2268	.5993	—.0035	.1739	.0123	.0044	.0221
70,500	.5445	.5447	.6457	.6458	.1337	.1338	.2383	.2384	.5952	—.0041	.1860	.0121	.0040	.0261
75,500	.5411	.5412	.6429	.6431	.1468	.1467	.2512	.2512	.5921	—.0031	.1990	.0130	.0049	.0310
80,500	.5213	.5211	.6222	.6222	.2183	.2181	.3218	.3217	.5717	—.0104	.2700	.0710	.0303	.0613
85,500	.5218	.5220	.6234	.6232	.2205	.2204	.3238	.3239	.5726	.0009	.2722	.0022	.0016	.0629
90,500	.5190	.5188	.6197	.6195	.2406	.2405	.3438	.3438	.5693	—.0043	.2922	.0200	.0078	.0707
95,500	.5178	.5178	.6198	.6198	.2593	.2595	.3630	.3630	.5688	—.0005	.3112	.0190	.0093	.0800
100,500	.5307	.5308	.6340	.6338	.2987	.2986	.4034	.4033	.5823	.0135	.3510	.0398	.0267	.1067
105,500	.5388	.5386	.6402	.6400	.3150	.3148	.4194	.4195	.5894	.0071	.3672	.0162	.0117	.1184
110,500	.5496	.5494	.6518	.6516	.3329	.3331	.4376	.4375	.6006	.0112	.3853	.0181	.0147	.1331
115,500	.5697	.5698	.6717	.6717	.3533	.3531	.4580	.4580	.6207	.0201	.4056	.0203	.0202	.1533
120,500	.5977	.5975	.6988	.6986	.3588	.3589	.4637	.4636	.6481	.0274	.4113	.0057	.0166	.1699
125,500	.6271	.6270	.7308	.7309	.3800	.3807	.4863	.4868	.6790	.0309	.4335	.0222	.0265	.1964
130,500	.6998	.6996	.8052	.8050	.4174	.4178	.5239	.5239	.7524	.0734	.4708	.0373	.0553	.2517
180,700	Maximum load.													

Size of bolts	1″	Maximum tension per sq. in. on net section of plate	60,800 lbs.
Pitch of bolts	3¼″	Maximum shear per sq. in. on bolts	38,300 lbs.
Thickness of plate	.44″	Maximum compression per sq. in. on plate,	136,900 lbs.
Width of plate	9.76″	Av. thickness of plate in front of bolts at fracture	.58″
Area net section of plate	2.97 sq. in.	Reduction of area of net section of plate	23%
Bolts were set up with 60 lbs. pull on 12-in. wrench.		Efficiency of joint	62%

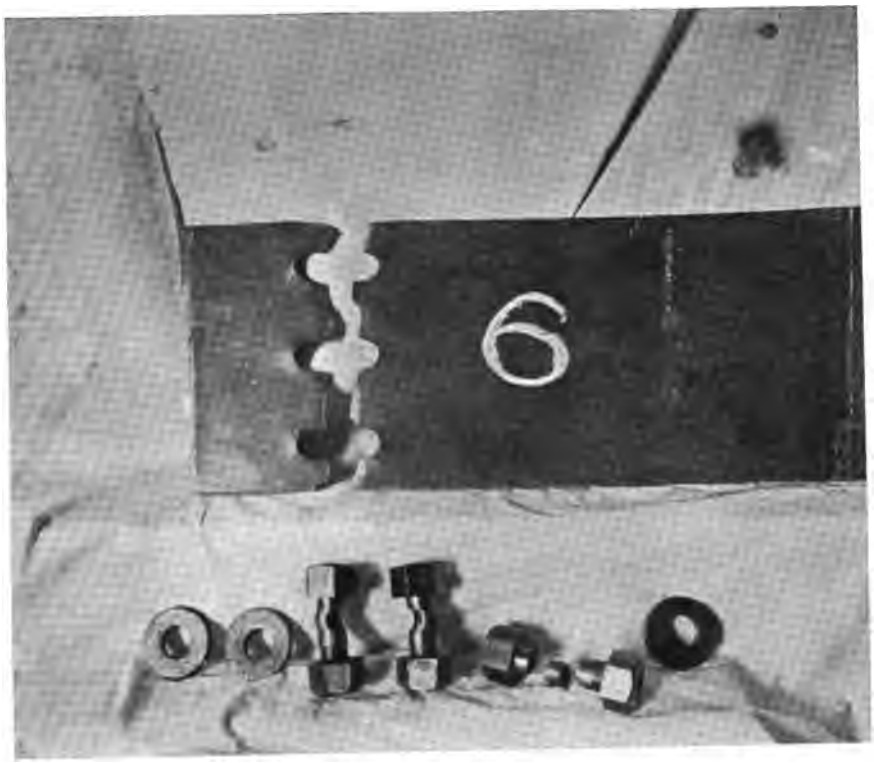


FIG. 7. BOLTED JOINT, NO. 6.

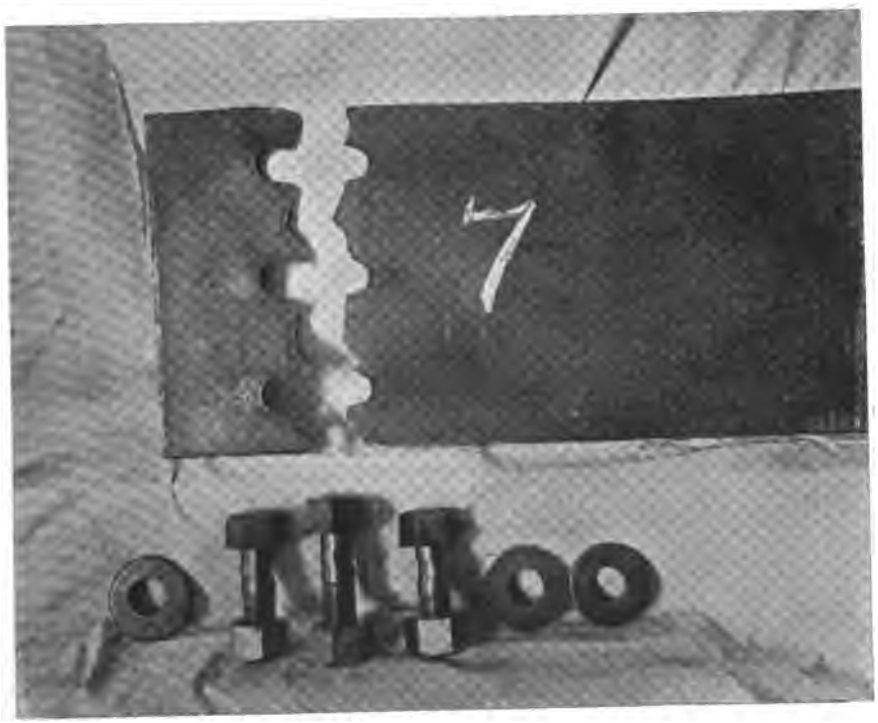


FIG. 8. BOLTED JOINT, NO. 7.

TEST ON BOLTED JOINT. No. 7. (FIG. 8.)

Date, December 5, 1895.

Loads.	North Side.				South Side.				North Side.		South Side.		Average difference.	Total difference.
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.		
500	.7285	.7286	.8469	.8471	.2549	.2549	.4038	.4036	.7878	....	.3293	....	....	....
5,500	.7325	.7323	.8442	.8441	.2577	.2579	.4022	.4023	.7883	.0005	.3300	.0007	.0006	.0006
10,500	.7345	.7344	.8444	.8444	.2587	.2585	.4014	.4013	.7894	.0011	.3300	—.0000	.0006	.0012
15,500	.7364	.7363	.8452	.8450	.2591	.2593	.4002	.4001	.7907	.0013	.3297	—.0003	.0005	.0017
	Load dropped off 2 hours.													
15,500	.7363	.7363	.8442	.8444	.2593	.2592	.4021	.4023	.7903	....	.3307	....	....	....
20,500	.7374	.7373	.8457	.8455	.2633	.2633	.4032	.4030	.7915	.0012	.3332	.0025	.0019	.0036
25,500	.7387	.7386	.8463	.8463	.2639	.2640	.4030	.4031	.7925	.0010	.3335	.0003	.0007	.0043
30,500	.7390	.7389	.8459	.8458	.2657	.2658	.4043	.4044	.7924	—.0001	.3351	.0016	.0008	.0051
35,500	.7393	.7393	.8462	.8460	.2669	.2671	.4058	.4058	.7927	.0003	.3364	.0013	.0008	.0059
40,500	.7387	.7388	.8453	.8453	.2700	.2700	.4077	.4079	.7920	—.0007	.3389	.0025	.0009	.0068
45,500	.7395	.7394	.8461	.8461	.2702	.2703	.4087	.4085	.7928	.0008	.3394	.0005	.0007	.0075
50,500	.7370	.7370	.8439	.8438	.2767	.2766	.4149	.4148	.7904	—.0024	.3458	.0064	.0020	.0095
55,500	.7364	.7364	.8431	.8432	.2797	.2797	.4177	.4178	.7898	—.0006	.3487	.0029	.0012	.0107
	Load dropped off 21 hours.													
55,500	.7252	.7253	.8430	.8430	.2794	.2794	.4173	.4172	.7841	....	.3483	....	....	....
60,500	.7300	.7300	.8422	.8421	.2830	.2830	.4209	.4210	.7861	.0020	.3520	.0037	.0028	.0135
65,500	.7273	.7271	.8391	.8393	.2942	.2941	.4324	.4323	.7832	—.0029	.3632	.0112	.0042	.0177
70,500	.7274	.7276	.8396	.8393	.2962	.2960	.4338	.4340	.7836	.0004	.3650	.0018	.0011	.0188
75,500	.7274	.7276	.8395	.8396	.2984	.2983	.4364	.4363	.7835	—.0001	.3673	.0023	.0011	.0199
80,500	.7265	.7265	.8387	.8387	.3039	.3040	.4424	.4422	.7826	—.0009	.3731	.0058	.0025	.0224
85,500	.7242	.7242	.8368	.8366	.3137	.3137	.4512	.4510	.7804	—.0022	.3824	.0093	.0035	.0259
90,500	.7224	.7222	.8347	.8348	.3237	.3235	.4621	.4621	.7785	—.0019	.3928	.0104	.0042	.0301
95,500	.7178	.7176	.8296	.8297	.3459	.3460	.4850	.4848	.7737	—.0048	.4154	.0226	.0089	.0390
100,500	.7176	.7174	.8300	.8302	.3516	.3517	.4904	.4906	.7738	.0001	.4211	.0057	.0029	.0419
105,500	.7180	.7180	.8307	.8309	.3610	.3611	.4996	.4998	.7744	.0006	.4304	.0093	.0049	.0468
110,500	.7224	.7222	.8346	.8348	.3683	.3685	.5077	.5078	.7785	.0041	.4381	.0077	.0059	.0527
115,500	.7284	.7283	.8418	.8419	.3795	.3793	.5193	.5192	.7851	.0066	.4493	.0112	.0089	.0636
120,500	.7261	.7260	.8400	.8400	.4007	.4007	.5418	.5417	.7830	—.0021	.4712	.0219	.0099	.0735
125,500	.7308	.7309	.8451	.8453	.4221	.4221	.5634	.5632	.7880	.0050	.4927	.0215	.0132	.0867
130,500	.7356	.7356	.8522	.8521	.4383	.4385	.5829	.5828	.7939	.0059	.5106	.0179	.0119	.0986
135,500	.7468	.7470	.8627	.8627	.4636	.4638	.6062	.6063	.8048	.0109	.5350	.0244	.0176	.1162
140,500	.7612	.7612	.8787	.8789	.4698	.4698	.6125	.6123	.8200	.0052	.5411	.0061	.0056	.1218
145,500	.7773	.7774	.8958	.8958	.4905	.4905	.6372	.6370	.8366	.0166	.5638	.0227	.0196	.1414
150,500	.7999	.7997	.9167	.9169	.5106	.5104	.6532	.6534	.8583	.0217	.5819	.0181	.0199	.1613
155,500	.8258	.8260	.9474	.9474	.5266	.5266	.6792	.6792	.8866	.0283	.6029	.0210	.0246	.1859
160,500	.8511	.8513	.9744	.9746	.5528	.5527	.7012	.7014	.9128	.0262	.6270	.0241	.0251	.2110
165,500	.8920	.8922	1.0162	1.0164	.5796	.5796	.7355	.7355	.9542	.0414	.6575	.0305	.0359	.2469
170,500	.9336	.9340	1.0584	1.0589	.6070	.6070	.7630	.7632	.9962	.0420	.6850	.0275	.0347	.2816
238,500	Maximum load. (Joint gave way by plate tearing)													

Size of bolts	1⅛″	Maximum tension per sq. in. on net section of plate	61,500 lbs.
Pitch of bolts	4″	Maximum shear per sq. in. on bolts	39,900 lbs.
Thickness of plate	.45″	Maximum compression per sq. in. on plate,	158,600 lbs.
Width of plate	12.00″	Av. thickness of plate in front of bolts at fracture	.59″
Area net section of plate	3.88 sq. in.	Reduction of area of net section of plate	25%
Bolts were set up with 60 lbs pull on 13-in wrench		Efficiency of joint	65%

TEST ON BOLTED JOINT. No. 8. (FIG. 9.)

Date, December 9, 1895.

Loads.	North Side.				South Side.				North Side.		South Side.		Average difference.	Total difference.
	Top.	Top.	Bottom.	Bottom.	Top.	Top.	Bottom.	Bottom.	Mean.	Difference.	Mean.	Difference.		
500	.6567	.6566	.6599	.6599	.1192	.1194	.1474	.1474	.6583	....	.1334	....	....	....
5,500	.6596	.6596	.6590	.6590	.1223	.1225	.1464	.1464	.6593	.0010	.1344	.0010	.0010	.0010
10,500	.6605	.6606	.6559	.6558	.1276	.1278	.1466	.1466	.6582	—.0009	.1372	.0028	.0009	.0019
15,500	.6605	.6605	.6548	.6549	.1294	.1294	.1473	.1475	.6577	—.0005	.1384	.0012	.0004	.0023
20,500	.6603	.6604	.6539	.6540	.1320	.1322	.1487	.1489	.6577	.0000	.1405	.0021	.0010	.0033
25,500	.6605	.6604	.6536	.6534	.1334	.1334	.1512	.1512	.6570	—.0007	.1423	.0018	.0006	.0039
30,500	.6605	.6603	.6528	.6530	.1353	.1355	.1512	.1512	.6567	—.0003	.1433	.0010	.0003	.0042
35,500	.6575	.6574	.6507	.6507	.1398	.1397	.1563	.1564	.6541	—.0026	.1481	.0048	.0011	.0053
	Load dropped off 70 hours.													
35,500	.6606	.6606	.6538	.6538	.1390	.1391	.1558	.1556	.6572	....	.1474	.0007	....	....
40,500	.6605	.6606	.6534	.6532	.1401	.1402	.1565	.1564	.6569	—.0003	.1483	.0009	.0003	.0056
45,500	.6599	.6597	.6521	.6520	.1447	.1446	.1609	.1607	.6559	—.0010	.1527	.0044	.0017	.0073
50,500	.6675	.6677	.6598	.6600	.1409	.1408	.1561	.1559	.6637	.0078	.1484	.0043	.0017	.0090
55,500	.6680	.6682	.6604	.6606	.1415	.1417	.1568	.1566	.6643	.0006	.1491	.0007	.0007	.0097
60,500	.6696	.6697	.6622	.6624	.1441	.1439	.1590	.1590	.6659	.0016	.1515	.0024	.0020	.0117
65,500	.6696	.6698	.6622	.6622	.1485	.1487	.1639	.1638	.6660	.0001	.1562	.0047	.0024	.0141
70,500	.6702	.6702	.6626	.6628	.1560	.1558	.1704	.1707	.6664	.0004	.1632	.0070	.0037	.0178
75,500	.6721	.6723	.6640	.6639	.1806	.1804	.1945	.1945	.6681	.0017	.1875	.0243	.0130	.0308
	Load dropped off 21 hours.													
75,500	.6450	.6449	.6359	.6357	.2341	.2343	.2428	.2428	.6404	....	.2385	....	....	....
80,500	.6385	.6387	.6298	.6296	.2535	.2533	.2625	.2626	.6341	—.0063	.2579	.0194	.0065	.0373
85,500	.6311	.6312	.6209	.6201	.2749	.2747	.2845	.2844	.6256	—.0085	.2796	.0217	.0066	.0439
90,500	.6148	.6149	.6063	.6064	.3244	.3244	.3336	.3335	.6106	—.0150	.3290	.0494	.0172	.0611
95,500	.6132	.6132	.6050	.6051	.3313	.3314	.3404	.3403	.6091	—.0015	.3358	.0068	.0026	.0637
100,500	.6044	.6045	.5967	.5966	.3590	.3592	.3700	.3700	.6005	—.0086	.3645	.0288	.0101	.0738
105,500	.5910	.5910	.5826	.5825	.4019	.4019	.4112	.4111	.5868	—.0137	.4065	.0419	.0141	.0879
110,500	.5839	.5840	.5757	.5757	.4262	.4262	.4349	.4350	.5798	—.0070	.4306	.0241	.0085	.0964
115,500	.5780	.5782	.5697	.5698	.4482	.4480	.4564	.4563	.5739	—.0059	.4522	.0216	.0078	.1042
120,500	.5709	.5708	.5621	.5620	.4746	.4746	.4833	.4835	.5664	—.0075	.4790	.0268	.0096	.1138
125,500	.5597	.5595	.5500	.5498	.5163	.5162	.5226	.5225	.5547	—.0117	.5194	.0404	.0143	.1281
130,500	.5544	.5543	.5471	.5470	.5412	.5413	.5500	.5499	.5507	—.0040	.5456	.0262	.0111	.1392
135,500	.5530	.5532	.5457	.5457	.5532	.5532	.5619	.5618	.5494	—.0013	.5575	.0119	.0053	.1445
140,500	.5574	.5572	.5489	.5488	.5791	.5792	.5875	.5874	.5531	+.0037	.5833	.0258	.0147	.1592
145,500	.5561	.5561	.5471	.5470	.6061	.6062	.6137	.6135	.5516	—.0016	.6099	.0266	.0125	.1717
150,500	.5670	.5672	.5575	.5576	.6319	.6320	.6374	.6374	.5623	+.0107	.6347	.0248	.0177	.1894
155,500	.5857	.5859	.5760	.5760	.6514	.6514	.6561	.6562	.5809	+.0186	.6538	.0191	.0188	.2082
160,500	.6055	.6055	.5951	.5953	.6729	.6730	.6790	.6790	.6003	+ 194	.6760	.0222	.0208	.2290
225,500	Maximum load. (Joint gave way by plate tearing.)													

Size of bolts	1⅛″	Maximum tension per sq. in. on net section of plate	58,100 lbs.
Pitch of bolts	4″	Maximum shear per sq. in. on bolts	37,600 lbs.
Thickness of plate	.45″	Maximum compression per sq. in. on plate,	148,600 lbs.
Width of plate	12.00″	Av. thickness of plate in front of bolts at fracture	.56″
Area net section of plate	3.88 sq. in.	Reduction of area of net section of plate,	26%
Bolts were set up with 60 lbs. pull on 13-in. wrench.		Efficiency of joint	62%

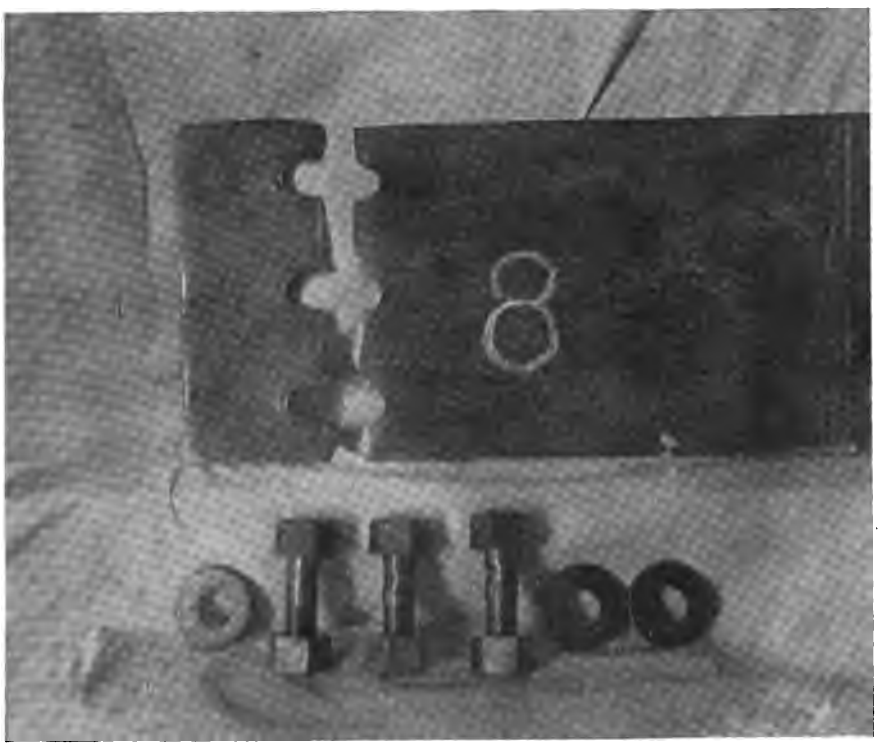


FIG. 9. BOLTED JOINT, NO. 8.

TENSION TEST. No. 21.

Specimen, Steel Boiler Plate. Date, December 12, 1895.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.
500	.3368	.3368	.4003	.4003	.3686	....
3,500	.3390	.3391	.4012	.4012	.3701	.0015
6,500	.3408	.3408	.4025	.4023	.3716	.0015
500	.3396	.3398	.3988	.3988	.3692	.0024
14,000	.3442	.3443	.4049	.4051	.3746	....
15,000	.3447	.3448	.4052	.4054	.3750	.0004
16,000	.3451	.3452	.4058	.4059	.3755	.0005
17,000	.3457	.3458	.4062	.4061	.3760	.0005
18,000	.3463	.3464	.4066	.4066	.3764	.0004
19,000	.3469	.3470	.4074	.4072	.3771	.0007
20,000	.3472	.3473	.4077	.4078	.3775	.0004
21,000	.3478	.3477	.4086	.4087	.3782	.0007
22,000	.3485	.3487	.4102	.4102	.3794	.0012
23,000	.3494	.3493	.4123	.4125	.3809	.0015

Length between clamps	8″	Area of original section; sq. ins.	.649
Dimensions of cross section	.43″ x 1.51″	Elastic limit; lbs. per sq. in.	27,700
Elastic limit	18,000 lbs.	Maximum load; lbs. per sq. in. orig. sect.	69,200
Maximum load	44,930 lbs.	Area of fractured section; sq. in.	.328
Dimensions of fractured section	.29″ x 1.13″	Reduction of area of cross section; per cent.,	49.5
Ultimate extension	1.87″	Ultimate extension; per cent.	23.4
Elastic elongation for 6,000 lbs. load equals	.0024″	Modulus of elasticity	30,800,000

TENSION TEST. No. 22.

Specimen, Boiler Plate. Date, December 13, 1895.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.
500	.3730	.3731	.4116	.4116	.3923	....
3,500	.3748	.3750	.4126	.4126	.3937	.0014
6,500	.3755	.3757	.4138	.4138	.3947	.0010
14,000	.3784	.3786	.4168	.4169	.3977	....
16,000	.3795	.3795	.4176	.4176	.3985	.0008
18,000	.3803	.3804	.4185	.4186	.3994	.0009
20,000	.3818	.3817	.4196	.4196	.4007	.0013
22,000	.3836	.3837	.4212	.4212	.4024	.0017
24,000	.3878	.3878	.4252	.4253	.4065	.0041

Length between clamps	8″	Area of original section; sq. ins.	.680
Dimensions of cross section	1.51″ x .45″	Elastic limit; lbs. per sq. in.	26,500
Elastic limit	18,000 lbs.	Maximum load; lbs. per sq. in. orig. sect.	65,500
Maximum load	44,500 lbs.	Area of fractured section; sq. in.	.339
Dimensions of fractured section	1.13″ x .30″	Reduction of area of cross section; per cent.,	50.1
Ultimate extension	1.69″	Ultimate extension; per cent.	21.1
Elastic elongation for 6,000 lbs. load equals	.0024″	Modulus of elasticity	29,400,000

TENSION TEST. No. 23.

Specimen, Steel Boiler Plate. Date, December 31, 1895.

Loads.	Micrometer Readings.				Mean.	Differences.
Actual.	1	2	1	2		Actual.
500	.4193	.4193	.3806	.3805	.3999	....
6,500	.4216	.4217	.3833	.3832	.4025	.0026
500	.4194	.4195	.3807	.3806	.4001	.0024
15,000	.4249	.4248	.3871	.3870	.4060	....
16,000	.4254	.4253	.3873	.3874	.4064	.0004
17,000	.4257	.4257	.3879	.3878	.4068	.0004
18,000	.4260	.4260	.3883	.3882	.4071	.0003
19,000	.4263	.4265	.3887	.3885	.4075	.0004
20,000	.4270	.4268	.3890	.3891	.4080	.0005
21,000	.4273	.4272	.3899	.3898	.4086	.0006
22,000	.4279	.4279	.3907	.3907	.4193	.0007
23,000	.4288	.4286	.3916	.3915	.4101	.0008
24,000	.4294	.4294	.3927	.3926	.4110	.0009
25,000	.4305	.4305	.3942	.3943	.4124	.0014

Length between clamps	8″	Area of original section; sq. ins.	.660
Dimensions of cross section	0.44″ x 1.50″	Elastic limit; lbs. per sq. in.	28,800
Elastic limit	19,000 lbs.	Maximum load; lbs. per sq. in. orig. sect.	69,700
Maximum load	46,000 lbs.	Area of fractured section; sq. in	.396
Dimensions of fractured section	0.33″ x 1.20″	Reduction of area of cross section; per cent.,	40.0
Ultimate extension	1.69″	Ultimate extension; per cent.	21.1
Elastic elongation for 6,000 lbs. load equals	.0024″	Modulus of elasticity	30,300,000

TENSION TEST. No. 30.

Specimen, Bolt Steel. Date, March 6, 1896.

Loads.	Micrometer Readings.				Mean.	Differences.
Actual.	1	2	1	2		Actual.
500	.4339	.4338	.0196	.0196	.2267	....
3,500	.4366	.4368	.0215	.0213	.2291	.0023
6,500	.4390	.4390	.0237	.0237	.2314	.0023
19,000	.4452	.4453	.0330	.0331	.2391	....
20,000	.4493	.4493	.0342	.0340	.2417	.0026
21,000	.4504	.4503	.0347	.0349	.2426	.0009
22,000	.4504	.4504	.0358	.0358	.2431	.0005
23,000	.4515	.4513	.0370	.0370	.2442	.0011
24,000	.4521	.4520	.0378	.0380	.2449	.0007
25,000	.4523	.4521	.0396	.0396	.2459	.0010
26,000	.4532	.4528	.0411	.0411	.2470	.0011
27,000	Piece would not hold load.					

Length between clamps	10″	Area of original section; sq. ins.	.443
Dimension of cross section	.7509″ dia.	Elastic limit; lbs. per sq. in.	58,700
Elastic limit	26,000 lbs.	Maximum load; lbs. per sq. in. orig. sect.	94,400
Maximum load	41,800 lbs.	Area of fractured section; sq. in.	.221
Dimension of fractured section	.5310″ dia.	Reduction of area of cross section; per cent.,	50.0
Ultimate extension	2.06″	Ultimate extension; per cent.	20.6
Elastic elongation for 6,000 lbs. load equals,	.0046″	Modulus of elasticity	29,500,000

TENSION TEST. No. 31.

Specimen, Bolt Steel. Date, March 7, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.
500	—.0062	—.0063	—.0156	—.0157	—.0110	....
3,500	—.0033	—.0034	—.0139	—.0141	—.0087	.0023
6,500	—.0015	—.0015	—.0116	—.0114	—.0065	.0023
20,000	—.0003	—.0004	+.0081	+.0081	+.0039	....
21,000	+.0087	+.0087	+.0009	+.0008	+.0048	.0009
22,000	+.0091	+.0089	+.0020	+.0022	+.0056	.0008
23,000	+.0095	+.0094	+.0034	+.0036	+.0065	.0009
24,000	+.0101	+.0100	+.0048	+.0048	+.0074	.0009
25,000	+.0106	+.0109	+.0063	+.0060	+.0084	.0010
26,000	+.0112	....	+.0079	....	+.0095	.0011
27,000	Piece would not hold load.					

Length between clamps	10″	Area of original section; sq. ins.	.441
Dimension of cross section	.7495″ dia.	Elastic limit; lbs. per sq. in.	58,900
Elastic limit	26,000 lbs.	Maximum load; lbs. per sq. in. orig. sect.,	99,300
Maximum load	43,800 lbs.	Area of fractured section; sq. in.	.215
Dimension of fractured section	.5237″ dia.	Reduction of area of cross section; per cent.,	51.2
Ultimate extension	2.12″	Ultimate extension; per cent.	21.2
Elastic elongation for 6,000 lbs. load equals,	.0046″	Modulus of elasticity	29,600,000

TENSION TEST. No. 32.

Specimen, Bolt Steel. Date, March 11, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.
500	.0402	.0403	—.0164	—.0165	.0119	....
3,500	.0427	.0426	—.0143	—.0145	.0141	.0022
6,500	.0448	.0447	—.0117	—.0118	.0165	.0024
20,000	.0564	.0564	—.0019	—.0018	.0273	....
21,000	.0574	.0574	—.0016	—.0016	.0279	.0006
22,000	.0588	.0586	—.0012	—.0011	.0288	.0009
23,000	.0596	.0595	—.0003	—.0005	.0296	.0008
24,000	.0603	.0603	+.0002	+.0002	.0303	.0007
25,000	.0612	.0612	+.0014	+.0014	.0313	.0010
26,000	Piece would not hold the load.					

Length between clamps	10″	Area of original section; sq. ins.	.441
Dimension of cross section	.749″ dia.	Elastic limit; lbs. per sq. in.	56,700
Elastic limit	25,000 lbs.	Maximum load; lbs. per sq. in. orig. sect.	95,100
Maximum load	41,890 lbs.	Area of fractured section; sq. in.	.219
Dimension of fractured section	.528″ dia.	Reduction of area of cross section; per cent.,	50.3
Ultimate extension	2.06″	Ultimate extension; per cent.	20.6
Elastic elongation for 6,000 lbs. load equals,	.0046″	Modulus of elasticity	29,600,000

Tests on Bolted Joints. (Boston Bridge Works.)

These joints were furnished by the Boston Bridge Works, and were designed to show the efficiency of a rough bolted joint. The form of the joints is indicated by the cut. From one to four bolts were used on each side of the joint, the bolts being placed in line as shown in the sketch. These bolts were all rough forged iron bolts of standard dimensions. The holes in the plate were punched, making a loose fit for the bolts. All the nuts were set up hard before breaking. Both one and two battens were used on each style of joint. When thin plate is used, the shearing strength of the bolts is figured on the nominal area, corresponding to the nominal diameter of the bolts, and the effective area figured on the diameter at the bottom of the threads, this being the area to resist the shear when a thin plate and cover strips are used.

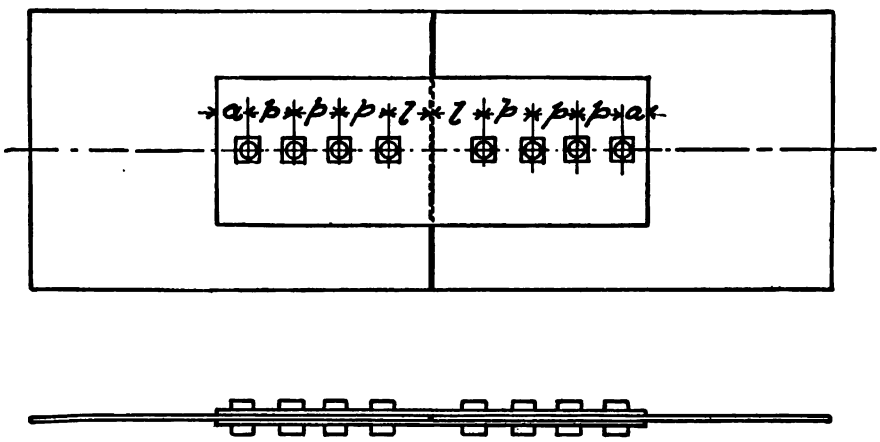


Fig. 10. Form of Bolted Joint.

TESTS ON BOLTED JOINTS. (BOSTON BRIDGE WORKS.)

No. of test.	No. of joint.	Diameter of bolts. (Inches.)	Number of bolts.	ϕ. (Inches.)	l. (Inches.)	a. (Inches.)	Thickness of plate. (Inches.)	Width of plate. (Inches.)	No. of battens.	Thickness of battens. (Inches.)	Width of battens. (Inches.)	Length of battens. (Inches.)	Maximum load.	Maximum shear on bolts. Nominal area. (Lbs. per sq. in.)	Maximum shear on bolts. Effective area. (Lbs. per sq. in.)	Maximum shear on plate. (Lbs. per sq. in.)	Maximum compression in front of bolts. (Lbs. per sq. in.)	Manner of breaking.
1	1	1	1	..	1	1	1	2	1	1	2	6	9,000	29,300	44,600	12,000	57,600	Bolt sheared.
2	1	1	1	..	1	1	1	2	1	1	2	6	10,100	32,900	50,000	13,500	64,600	Bolt sheared.
3	2	1	1	..	1	1	1	2	2	1	2	6	19,700	32,100	48,800	26,300	126,000	Bolt sheared.
4	2	1	1	..	1	1	1	2	2	1	2	6	17,800	29,000	44,100	23,700	114,000	Bolt sheared.
5	3	1	4	2	1	1	1	4	2	1	2	8	31,000	25,300	38,400	6,200	49,600	Holts sheared.
6	3	1	4	2	2	1	1	8	1	1	2	23	35,000	28,500	43,300	7,000	56,000	Bolts sheared.
7	4	1	4	2	2	1	1	8	2	1	2	23	66,200	27,000	41,000	13,200	105,900	Bolts sheared.
8	4	1	4	2	2	1	1	8	2	1	2	23	68,800	28,000	42,600	13,800	110,100	Bolts sheared.
9	4	1	4	2	2	1	1	8	2	1	2	23	15,800	26,300	37,600	21,100	72,200	Bolt sheared.
10	5	1	1	..	1	1	1	4	1	1	4	6	17,600	29,300	41,900	23,500	80,500	Bolt sheared.
11	6	1	1	..	1	1	1	4	1	1	4	6	20,400	17,000	24,300	27,200	93,300	Plate sheared in front of bolt.
12	6	1	1	..	1	1	1	4	2	1	4	6	19,700	16,400	23,500	26,300	90,100	Plate sheared in front of bolt.
13	7	1	4	3	3	1	1	15½	2	1	4	27	69,000	28,700	41,100	11,500	78,900	Bolts sheared.
14	7	1	4	3	3	1	1	15½	2	1	4	27	71,000	29,500	42,300	11,800	81,100	Bolts sheared.
15	8	1	4	3	3	1	1	18	2	1	4	27	145,100	30,200	43,200	16,100	110,500	Bolts sheared.
16	8	1	4	3	3	1	1	18	2	1	4	27	147,300	30,600	43,800	18,700	112,200	Bolts sheared.
17	9	1	1	..	1	1	1	2	1	1	2	6	5,600	18,200	....	2,500	11,900	Bolt sheared.
18	9	1	1	..	1	1	1	2	1	1	2	6	11,600	37,800	....	5,200	24,700	Bolt sheared.
19	10	1	1	..	1	1	1	2	2	1	2	6	13,300	21,700	....	5,900	28,400	Bolt sheared.
20	10	1	1	..	1	1	1	2	2	1	2	6	14,700	23,900	....	6,500	31,400	Bolt sheared.
21	11	1	4	2	2	1	1	3½	1	1	3½	23	40,100	32,700	....	2,700	21,400	Bolts sheared.
22	11	1	4	2	2	1	1	3½	1	1	3½	23	44,800	36,500	....	3,000	23,900	Bolts sheared.
23	12	1	4	2	2	1	1	5½	2	1	3½	23	79,000	32,500	....	5,800	42,100	Bolts sheared.
24	12	1	4	2	2	1	1	5½	2	1	3½	23	79,700	33,800	....	5,900	42,600	Bolts sheared.
25	13	1	1	..	3	1	2	2½	1	2	2½	9	19,700	32,800	....	4,400	30,000	Batten broke by tension through bolt hole.
26	13	1	1	..	3	1	2	2½	1	2	2½	9	25,000	41,600	....	5,600	38,100	Bolt sheared.
27	14	1	1	..	3	1	2	3½	2	2	2½	9	38,800	32,300	....	8,600	59,100	Bolts sheared.
28	14	1	1	..	3	1	2	3½	2	2	2½	9	38,000	31,600	....	8,400	57,900	Bolt sheared.
29	15	1	4	3	3	1	1	6	1	1	6	27	79,900	33,200	....	4,400	30,400	Bolts sheared.
30	15	1	4	3	3	1	1	6	1	1	6	27	78,500	32,600	....	4,400	29,900	Bolts sheared.
31	16	1	4	3	3	1	1	10½	2	1	6	27	161,000	33,500	....	10,200	61,300	Holts sheared.
32	16	1	4	3	3	1	1	10½	2	1	6	27	145,400	30,200	....	9,200	55,400	Bolts sheared.

Wrought Iron Pipe Columns.

SUMMARY OF TESTS.

Date of Test.	Nominal size of pipe.	Inside diameter.	Outside diameter.	Diameter of flanges.	Length of inside of flanges.	Gauge length.	Maximum load.	Area of cross section.	Maximum load per sq. in.	Compression. Modulus of elasticiy.	$\frac{l}{\rho}$, or ratio of length to radius of gyration.
	In.	In.	In.	In.	In	In.	Lbs.	Sq. in.	Lbs.		
March 31, 1896	2	2.06	2.37	7	6 9/16	51	30,000	1.08	27,800	24,300,000	88.8
" 30 "	2	2.04	2.39	7	6 9/16	51	29,800	1.22	24,500	22,200,000	89.1
" 26 "	2½	2.50	2.89	8	9 3/16	86	34,500	1.65	20,900	25,200,000	98.1
" 27 "	2½	2.48	2.88	8	9 3/16	86	37,000	1.68	22,000	25,900,000	98.4
" 10 "	3	3.06	3.44	8	9 3/16	86	45,500	1.94	23,500	27,700,000	81.4
" 12 "	3	3.09	3.48	8	9 3/16	86	51,000	2.01	25,300	25,100,000	80.5
" 24 "	3½	3.60	4.00	9	10 5/16	100.5	55,000	2.39	23,000	25,200,000	78.2
" 25 "	3½	3.59	3.99	9	10 5/16	100.5	65,000	2.39	27,200	24,600,000	78.5
" 16 "	4	4.07	4.53	9	11 7/16	100.5	80,000	3.11	25,700	25,800,000	77.1
" 20 "	4	4.09	4.50	9	11 7/16	100.5	69,000	2.76	25,000	24,900,000	77.3

These were tested in the same manner as the spruce columns already described in Technology Quarterly, Vol. 8, pp. 219–247, 1895.

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 31, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.9466	.94670	.....	.55	.44	.6575	.65745	....	.32	.32	.....	.....	.....
	.9468					.6574							
7,500	.9423	.94240	.0043	.55	.44	.6521	.65210	.0054	.32	.32	.00485	.000	.000
	.9425					.6521							
10,000	.9375	.93745	.0050	.55	.45	.6473	.64730	.0048	.31	.32	.00490	—.005	.005
	.9374					.6473							
12,500	.9330	.93300	.0045	.55	.45	.6430	.64295	.0044	.31	.32	.00445	.000	.000
	.9330					.6429							
15,000	.9275	.92740	.0056	.55	.45	.6383	.63825	.0047	.31	.32	.00515	.000	.000
	.9273					.6382							
17,500	.9220	.92190	.0055	.55	.45	.6342	.63430	.0040	.31	.32	.00475	.000	.000
	.9218					.6344							
20,000	.9158	.91575	.0062	.55	.45	.6301	.63005	.0043	.31	.32	.00525	.000	.000
	.9157					.6300							
22,500	.9102	.91020	.0056	.57	.41	.6240	.62405	.0060	.33	.28	.00580	.020	—.040
	.9102					.6241							
25,000	.9043	.90440	.0058	.54	.36	.6188	.61875	.0053	.33	.25	.00555	—.015	—.040
	.9045					.6187							
27,500	.....	.....	.....	.54	.36	.....	.....	....	.33	.25	.....	.000	.000

Nominal size of pipe	2″	Compression (5,000–15,000)	.0194″
Actual inside diameter	2.06″	Area of cross section	1.08 sq. in.
Actual outside diameter	2.37″	Maximum load	27,800 lbs. per sq. in.
Length inside of flanges	6 9/16″	Modulus of elasticity (5,000–15,000)	24,300,000
Diameter of flanges	7″	$\frac{l}{\rho}$	88.8
Gauge length	51″		
Maximum load	30,000 lbs.		

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 30, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.7139 .7137	.7138	.....	.30	.42	.7985 .7985	.7985	.....	.33	.45	.....	....	....
7,500	.7089 .7088	.7089	.0049	.30	.42	.7927 .7927	.7927	.0058	.33	.45	.00535	.000	.000
10,000	.7043 .7044	.7044	.0045	.30	.42	.7888 .7889	.7889	.0038	.33	.45	.00415	.000	.000
12,500	.6995 .6995	.6995	.0049	.30	.42	.7841 .7842	.7842	.0047	.33	.45	.00480	.000	.000
15,000	.6953 .6952	.6953	.0042	.30	.42	.7792 .7794	.7793	.0049	.33	.45	.00455	.000	.000
17,500	.6908 .6909	.6909	.0044	.30	.42	.7742 .7742	.7742	.0051	.33	.45	.00475	.000	.000
20,000	.6879 .6878	.6879	.0030	.30	.42	.7682 .7680	.7681	.0061	.32	.45	.00455	—.005	.000
22,500	.6857 .6857	.6857	.0022	.28	.42	.7632 .7630	.7631	.0050	.30	.45	.00360	—.020	.000
25,000	.6836 .6835	.6835	.0022	.26	.41	.7542 .7544	.7543	.0088	.29	.45	.00550	—.015	—.005
27,500	.....	.....	.....	.24	.41	.....	.....	.....	.26	.44	.....	—.025	—.005

Nominal size of pipe	2″	Maximum load	29,800 lbs.
Actual inside diameter	2.04″	Compression (5,000–15,000)	.01885″
Actual outside diameter	2.39″	Area of cross section	1.22 sq. in.
Length inside of flanges	69$\frac{15}{16}$″	Maximum load	24,500 lbs. per sq. in.
Diameter of flanges	7″	Modulus of elasticity	22,200,000
Gauge length	51″	$\frac{l}{\rho}$	89.1

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 26, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.5742	.5743	.....	.60	.67	.4117	.4117	.....	.40	.60	.....	.....	....
	.5743					.4116							
10,000	.5660	.5660	.0085	.58	.67	.3999	.4000	.0117	.40	.60	.01000	—.010	.000
	.5660					.4000							
15,000	.5584	.5585	.0075	.57	.68	.3873	.3872	.0128	.38	.62	.01015	—.015	.015
	.5586					.3871							
20,000	.5502	.5501	.0084	.56	.68	.3740	.3739	.0133	.37	.63	.01085	—.010	.005
	.5500					.3738							
25,000	.5401	.5402	.0099	.56	.68	.3618	.3619	.0120	.36	.65	.01095	—.005	.010
	.5403					.3620							
30,000	.5273	.5272	.0130	.55	.73	.3483	.3483	.0136	.35	.65	.01330	—.010	.035
	.5271					.3483							

Nominal size of pipe	2½″	Maximum load	34,500 lbs.
Actual inside diameter	2.50″	Compression (5,000–20,000)	0.0310″
Actual outside diameter	2.89″	Area of cross section	1.65 sq. in.
Length inside of flanges	93$\frac{13}{16}$″	Maximum load	20,900 lbs. per sq. in.
Diameter of flanges	8″	Modulus of elasticity	25,200,000
Gauge length	86″	$\frac{l}{\rho}$	98.1

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 27, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.4060	.4061	....	.17	.20	.6430	.6429	.....	.40	.37	.....	.....	.....
	.4061					.6428							
10,000	.4002	.4002	.0059	.16	.17	.6302	.6301	.0128	.39	.30	.00935	—.010	—.050
	.4002					.6300							
15,000	.3911	.3912	.0090	.16	.16	.6191	.6191	.0110	.38	.29	.01000	—.005	—.010
	.3912					.6191							
20,000	.3811	.3811	.0101	.16	.15	.6086	.6086	.0105	.38	.27	.01030	.000	—.015
	.3811					.6085							
25,000	.3737	.3738	.0073	.15	.15	.5944	.5945	.0141	.36	.27	.01070	—.015	.000
	.3739					.5945							
30,000	.3636	.3636	.0102	.15	.15	.5840	.5840	.0105	.36	.26	.01035	.000	—.005
	.3635					.5840							
35,000	.....	.....	.....	.13	.15	.....	.....	.....	.34	.25	.....	—.020	—.005

Nominal size of pipe	2½″	Maximum load	37,000 lbs.
Actual inside diameter	2.48″	Compression (5,000–20,000)	.0297″
Actual outside diameter	2.88″	Area of cross section	1.68 sq. in.
Length inside of flanges	93½″	Maximum load	22,000 lbs. per sq. in.
Diameter of flanges	8″	Modulus of elasticity	25,900,000
Gauge length	86″	$\frac{l}{\rho}$	98.4

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 10, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
1,500	1.0283 1.0285	1.0284	.....	.20	.40	.6748 .6748	.6748	.....	25	.37	.....	.....	.....
3,500	1.0286 1.0284	1.0285	—.0001	.16	.40	.6679 .6681	.6680	.0068	.20	.29	.00335	—.045	—.040
5,500	1.0245 1.0245	1.0245	.0040	.17	.40	.6636 .6636	.6636	.0044	.21	.29	.00420	.010	.000
7,500	1.0221 1.0219	1.0220	.0025	.16	.39	.6594 .6596	.6595	.0041	.20	.28	.00330	—.010	—.010
7,500	1.0223 1.0225	1.0224	.....	.17	.37	.6608 .6609	.6609	.....	.21	.28	.....	.010	—.010
9,500	1.0196 1.0195	1.0196	.0028	.16	.37	.6569 .6567	.6568	.0041	.21	.26	.00345	—.005	—.010
11,500	1.0170 1.0168	1.0169	.0027	.15	.37	.6530 .6529	.6530	.0038	.20	.25	.00325	—.010	—.005
13,500	1.0139 1.0140	1.0140	.0029	.15	.37	.6492 .6492	.6492	.0038	.20	.24	.00335	.000	—.005
15,500	1.0108 1.0110	1.0109	.0031	.15	.37	.6453 .6454	.6454	.0038	.20	.24	.00345	.000	.000
17,500	1.0079 1.0078	1.0079	.0030	.15	.37	.6416 .6415	.6416	.0038	.20	.24	.00340	.000	.000
19,500	1.0048 1.0049	1.0049	.0030	.15	.37	.6378 .6380	.6379	.0037	.20	.24	.00335	.000	.000
21,500	1.0016 1.0014	1.0015	.0034	.15	.36	.6341 .6342	.6342	.0037	.19	.24	.00355	—.005	—.005
24,000	.9969 .9970	.9970	.0045	.15	.36	.6298 .6299	.6299	.0043	.19	.24	.00440	.000	.000
26,500	.9933 .9935	.9934	.0036	.15	.36	.6251 .6252	.6252	.0047	.19	.23	.00415	.000	—.005
29,000	.9889 .9889	.9889	.0045	.15	.36	.6201 .6203	.6202	.0050	.19	.21	.00425	.000	—.010
31,500	.9855 .9854	.9855	.0034	.14	.36	.6153 .6151	.6152	.0050	.19	.21	.00420	—.005	.000
33,000	.9839 .9839	.9839	.0016	.14	.36	.6120 .6118	.6119	.0033	.18	.21	.00245	—.005	.000
35,500	.9792 .9793	.9793	.0046	.14	.35	.6068 .6070	.6069	.0050	.17	.20	.00480	—.005	—.010
38,000	.9750 .9749	.9750	.0043	.14	.34	.6010 .6011	.6011	.0058	.16	.20	.00505	—.005	—.005
40,500	.9711 .9710	.9711	.0039	.13	.33	.5935 .5934	.5935	.0076	.16	.21	.00575	—.005	.000
43,000	.9672 .9672	.9672	.0039	.12	.32	.5840 .5840	.5840	.0095	.15	.19	.00670	—.010	—.015

Nominal size of pipe	3″	Maximum load	45,500 lbs.
Actual inside diameter	3.06″	Compression (4,500–14,500)	.0160″
Actual outside diameter	3.44″	Area of cross section	1.94 sq. in.
Length inside of flanges	93$\frac{13}{16}$″	Maximum load	23,500 lbs. per sq. in.
Diameter of flanges	8$\frac{1}{2}$″	Modulus of elasticity	27,700,000
Gauge length	86″	$\frac{l}{\rho}$	81.4

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 12, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
2,500	.3190 .3192	.3191	.....	.16	.28	.4520 .4522	.4521	.....	.26	.33	.....	.....	.....
5,000	.3115 .3115	.3115	.0076	.19	.26	.4533 .4521	.4522	.0001	.28	.30	.00385	.025	—.025
7,500	.3053 .3053	.3053	.0062	.20	.25	.4487 .4485	.4486	.0036	.29	.29	.00490	.010	—.010
10,000	.2995 .2996	.2996	.0057	.21	.25	.4458 .4456	.4457	.0029	.29	.28	.00430	.005	—.005
12,500	.2989 .2988	.2989	.0007	.22	.25	.4431 .4433	.4432	.0025	.30	.28	.00160	.010	.000
15,000	.2882 .2884	.2883	.0106	.22	.25	.4400 .4402	.4401	.0031	.30	.28	.00665	.000	.000
17,500	.2836 .2836	.2836	.0047	.23	.25	.4362 .4360	.4361	.0041	.31	.27	.00440	.010	—.005
20,000	.2794 .2792	.2793	.0043	.23	.25	.4319 .4321	.4320	.0041	.31	.27	.00420	.000	.000
22,500	.2749 .2750	.2750	.0043	.23	.25	.4279 .4281	.4280	.0040	.31	.27	.00415	.000	.000
25,000	.2708 .2708	.2708	.0042	.22	.25	.4232 .4231	.4232	.0048	.31	.29	.00450	—.005	.010
27,500	.2665 .2663	.2664	.0044	.22	.26	.4195 .4193	.4192	.0040	.31	.28	.00420	.000	.000
30,000	.2620 .2619	.2620	.0044	.23	.26	.4140 .4139	.4140	.0052	.31	.28	.00480	.005	.000
32,500	.2575 .2573	.2574	.0046	.23	.26	.4107 .4105	.4106	.0034	.31	.29	.00400	.000	.005
35,000	.2533 .2533	.2533	.0041	.23	.26	.4062 .4064	.4063	.0043	.31	.29	.00420	.000	.000
37,500	.2447 .2448	.2448	.0085	.24	.27	.4032 .4034	.4031	.0032	.32	.30	.00585	.010	.010
40,000	.2380 .2378	.2379	.0069	.25	.28	.4004 .4004	.4004	.0027	.33	.30	.00480	.010	.005
42,500	.2334 .2333	.2334	.0045	.25	.28	.3964 .3964	.3964	.0040	.33	.30	.00425	.000	.000
45,000	.2266 .2264	.2265	.0069	.26	.27	.3931 .3931	.3931	.0033	.34	.31	.00510	.010	.000
47,500	....	....	.....	.29	.28	.....	....	.....	.36	.31	.....	.025	.005
50,000	.....	....	.....	.70	.30	.....	....	....	.62	.31	.....	.335	.010

Nominal size of pipe	3″	Maximum load	51,000 lbs.
Actual inside diameter	3.09″	Compression (2,500–22,500)	.0341″
Actual outside diameter	3.48″	Area of cross section	2.01 sq. in.
Length inside of flanges	93⅝″	Maximum load	25,300 lbs. per sq. in.
Diameter of flanges	8⅝″	Modulus of elasticity	25,100,000
Gauge length	86″	$\frac{l}{\rho}$	80.5

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 24, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.3700 .3668	.3669	.....	.30	.44	.2288 .2290	.2289	.....	.23	.32	.....	.....	.....
10,000	.3626 .3628	.3627	.0042	.30	.44	.2189 .2186	.2188	.0101	.22	.30	.00715	—.005	—.010
15,000	.3538 .3520	.3529	.0098	.30	.44	.2107 .2108	.2107	.0081	.22	.30	.00895	.000	.000
20,000	.3437 .3450	.3444	.0085	.30	.41	.2015 .2014	.2015	.0092	.22	.30	.00885	.000	—.015
25,000	.3373 .3368	.3370	.0074	.30	.40	.1929 .1928	.1928	.0087	.22	.29	.00805	.000	—.010
30,000	.3293 .3287	.3290	.0080	.30	.40	.1843 .1843	.1843	.0085	.22	.28	.00825	.000	—.005
35,000	.3198 .3199	.3198	.0092	.30	.40	.1757 .1757	.1757	.0086	.22	.28	.00890	.000	.000
40,000	.3114 .3115	.3115	.0083	.30	.38	.1662 .1662	.1662	.0095	.22	.26	.00890	.000	—.020
45,000	.3007 .3009	.3008	.0107	.30	.27	.1463 .1462	.1463	.0199	.20	.16	.01530	—.010	—.105
50,000	.....	.....	.....	.30	.27	.....	.....	.....	.20	.16	.....	.000	.000
55,000	.....	.....	.....	.29	.17	.....	.....	.....	.20	.06	.....	—.005	—.010

Nominal size of pipe	$3\frac{1}{2}''$	Maximum load	55,000 lbs.
Actual inside diameter	3.60″	Compression (5,000–35,000),	.05015″
Actual outside diameter	4.00″	Area of cross section	2.39 sq. in.
Length inside of flanges	$105\frac{1}{4}''$	Maximum load	23,000 lbs. per sq in.
Diameter of flanges	$9\frac{1}{8}''$	Modulus of elasticity	25,100,000 lbs.
Gauge length	100.5″	$\frac{l}{\rho}$	78.2

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 25, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.5876 .5875	.5876	.....	.55	.36	.6204 .6205	.6205	.....	.43	.49	.....	.....	.....
10,000	.5769 .5769	.5769	.0107	.55	.36	.6143 .6145	.6144	.0061	.44	.48	.00840	.005	—.005
15,000	.5680 .5679	.5680	.0089	.57	.36	.6068 .6069	.6069	.0075	.45	.47	.00820	.015	—.005
20,000	.5581 .5581	.5581	.0099	.57	.37	.5990 .5991	.5991	.0078	.45	.47	.00885	.000	.005
25,000	.5485 .5485	.5485	.0096	.57	.37	.5912 .5913	.5913	.0078	.46	.47	.00870	.005	.000
30,000	.5395 .5396	.5396	.0089	.58	.36	.5830 .5830	.5830	.0083	.46	.47	.00860	.005	—.005
35,000	.5305 .5305	.5305	.0091	.58	.36	.5750 .5750	.5750	.0080	.47	.46	.00855	.005	—.005
40,000	.5211 .5210	.5211	.0094	.59	.36	.5667 .5667	.5667	.0083	.47	.46	.00885	.005	.000
45,000	.5120 .5118	.5119	.0092	.58	.35	.5582 .5583	.5583	.0084	.47	.46	.00880	—.005	—.005
50,000	.....	.....	.....	.60	.35	.....	.....	.....	.47	.45	.....	.010	—.005
55,000	.....	.....	.....	.61	.35	.....	.....	.....	.50	.45	.....	.020	.000
60,000	.....	.....	.....	.70	.35	.....	.....	.....	.56	.43	.....	.075	—.010

Nominal size of pipe	$3\frac{1}{2}''$	Maximum load	65,000 lbs.
Actual inside diameter	3.59″	Compression (5,000–35,000),	.05130″
Actual outside diameter	3.99″	Area of cross section	2.39 sq. in.
Length inside of flanges	$105\frac{3}{8}''$	Maximum load	27,200 lbs. per sq. in.
Diameter of flanges	$9\frac{1}{4}''$	Modulus of elasticity	24,600,000 lbs.
Gauge length	100.5″	$\frac{l}{\rho}$	78.5

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 16, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.5067 .5066	.5067	.....	.14	.27	.6468 .6467	.6468	.....	.39	.08	.....	.....	.....
10,000	.5031 .5030	.5031	.0036	.14	.26	.6386 .6388	.6387	.0081	.38	.06	.00585	—.005	—.015
15,000	.4970 .4972	.4971	.0060	.14	.26	.6316 .6315	.6316	.0071	.38	.06	.00655	.000	.000
20,000	.4910 .4912	.4911	.0060	.15	.26	.6251 .6253	.6252	.0064	.37	.06	.00620	.000	.000
25,000	.4857 .4858	.4858	.0053	.15	.25	.6179 .6178	.6179	.0073	.37	.04	.00630	.000	—.015
30,000	.4798 .4799	.4799	.0059	.15	.25	.6108 .6108	.6108	.0071	.37	.04	.00650	.000	.000
35,000	.4739 .4739	.4739	.0060	.15	.25	.6038 .6038	.6038	.0070	.36	.04	.00650	—.005	.000
40,000	.4678 .4678	.4678	.0061	.15	.25	.5971 .5970	.5971	.0067	.36	.04	.00640	.000	.000
40,000	.4662 .4660	.4661	.....	.13	.09	.6065 .6065	.6065	. ...	.35	.14	.....	.....	.....
45,000	.4602 .4602	.4602	.0059	.11	.08	.5998 .5997	.5998	.0067	.35	.14	.00630	—.010	—.005
50,000	.4536 .4534	.4535	.0067	.11	.08	.5948 .5949	.5948	.0050	.35	.13	.00585	.000	—.005
55,000	.4480 .4480	.4480	.0055	.11	.07	.5884 .5886	.5885	.0063	.35	.13	.00590	.000	—.005
60,000	.4416 .4416	.4416	.0064	.10	.07	.5817 .5816	.5817	.0068	.35	.13	.00660	—.005	.000
65,000	.4357 .4357	.4357	.0059	.10	.07	.5747 .5749	.5748	.0069	.35	.13	.00640	.000	.000
70,000	.4301 .4301	.4301	.0056	.10	.09	.5664 .5664	.5664	.0084	.33	.13	.00700	—.010	.010
75,000	.4247 .4248	.4248	.0053	.07	.09	.5542 .5542	.5542	.0122	.31	.13	.00875	—.025	.000

Nominal size of pipe	4″	Maximum load	80,000 lbs.
Actual inside diameter	4.07″	Compression (5,000–35,000),	.0379″
Actual outside diameter	4.53″	Area of cross section	3.11 sq. in.
Length inside of flanges	$117\frac{7}{16}$″	Maximum load	25,723 lbs. per sq. in.
Diameter of flanges	$9\frac{1}{2}$″	Modulus of elasticity	25,800,000 lbs.
Gauge length	100.5″	$\frac{l}{\rho}$	77.1

Held load for a moment, then deflected, breaking cap on east end.

TEST OF WROUGHT IRON PIPE COLUMN.

Date, March 20, 1896.

Loads.	North Side.					South Side.					Average difference of micrometer readings.	Average difference of abscissæ.	Average difference of ordinates.
	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.	Micrometer readings.	Mean.	Difference.	Abscissæ.	Ordinates.			
5,000	.6079 .6079	.6079	.....	.57	.58	.4374 .4374	.4374	.....	.52	.54	.....	....	....
10,000	.6010 .6009	.6010	.0069	.57	.60	.4296 .4294	.4295	.0079	.52	.57	.00740	.000	.025
15,000	.5927 .5928	.5928	.0082	.58	.61	.4221 .4220	.4221	.0074	.52	.58	.00780	.005	.010
20,000	.5849 .5848	.5849	.0079	.58	.62	.4154 .4154	.4154	.0067	.52	.59	.00730	.000	.010
25,000	.5783 .5782	.5783	.0066	.58	.63	.4090 .4091	.4091	.0063	.53	.59	.00645	.005	.005
30,000	.5698 .5699	.5699	.0084	.58	.63	.4025 .4025	.4025	.0066	.53	.59	.00750	.000	.000
35,000	.5618 .5619	.5619	.0080	.59	.63	.3958 .3956	.3957	.0068	.53	.59	.00740	.005	.000
Load allowed to go up until column was thrown out of line.													
35,000	.4460 .4460	.4460	.....	.97	.63	.4010 .4010	.4010	.....	.93	1.15	.....	.390	.280
40,000	.4372 .4372	.4372	.0088	.98	.64	.3946 .3946	.3946	.0064	.94	1.16	.00760	.010	.010
45,000	.4284 .4284	.4284	.0088	.99	.65	.3879 .3880	.3880	.0066	.95	1.17	.00770	.010	.010
50,000	.4199 .4198	.4199	.0085	1.00	.66	.3815 .3816	.3816	.0064	.96	1.18	.00745	.010	.010
60,000	.....	.....	.....	1.06	1.15	.....	.....	.....	.99	1.21	.....	.045	.260

Nominal size of pipe	4″	Maximum load	69,000 lbs.
Actual inside diameter	4.09″	Compression (5,000–35,000),	.04385″
Actual outside diameter	4.50″	Area of cross section	2.76 sq. in.
Length inside of flanges	117⅛″	Maximum load	25,000 lbs. per sq. in.
Diameter of flanges	9½″	Modulus of elasticity	24,900,000 lbs.
Gauge length	100.5	$\frac{l}{\rho}$	77.3

Slight bend about two feet from end of pipe.

TRANSVERSE STRENGTH OF SPRUCE BEAMS.

No. of test.	Width and depth. (Inches.)	Distance between supports. (Feet.)	Manner of loading.	Breaking load.	Modulus of rupture. (Lbs. per sq. in.)	Modulus of elasticity. (Lbs. per sq. in.)	Maximum intensity of longitudinal shear. (Lbs. per sq. in.)	Manner of breaking.	Remarks.
505	6 x 12	15	Center.	14,800	4,670	....	153	Tension.	
507	4 x 11⅞	13	Center.	9,100	3,870	990,000	147	Tension.	
508	4 x 12	13	Center.	9,500	3,890	1,030,000	151	Tension.	
509	4 x 12	14	Center.	12,400	5,480	1,380,000	198	Tension.	
510	4⅛ x 11⅞	12	Center.	10,130	4,060	1,190,000	161	Tension.	
511	3⅞ x 11⅝	13	Center.	6,000	2,880	1,150,000	108	Tension.	
512	3⅞ x 12	12	Center.	10,170	4,100	1,020,000	172	Tension.	
513	4 x 12	14	Center.	9,600	4,270	974,000	155	Tension.	
514	4 x 12	12	Center.	10,400	3,930	976,000	165	Tension.	
515	4 x 12	12	Center.	8,780	3,320	883,000	139	Tension.	
516	4 x 12	13	Center.	12,260	5,030	1,110,000	195	Shear.	
521	4 x 12	12	Center.	11,650	4,400	1,090,000	185	Tension.	
525	4 x 12	14	Center.	10,640	4,690	1,110,000	169	Tension.	
526	1⅝ x 11⅝	19	Center.	4,230	5,480	1,420,000	143	Tension.	Beam buckled badly.
527	3⅝ x 11⅝	14	Center.	11,630	5,920	1,390,000	201	Tension.	
532	2 x 12	15	Center.	3,230	2,940	....	101	Tension and crushing.	

TRANSVERSE STRENGTH OF NORWAY PINE BEAMS.

No. of test.	Width and depth. (Inches.)	Distance between supports. (Feet.)	Manner of loading.	Breaking load.	Modulus of rupture. (Lbs. per sq. in.)	Modulus of elasticity. (Lbs. per sq. in.)	Maximum intensity of longitudinal shear. (Lbs. per sq. in.)	Manner of breaking.	Remarks.
528	2 x 11⅞	26	Center.	1,990	3,660	1,260,000	70	Tension.	
529	2 x 11⅞	26	Center.	3,690	6,340	2,020,000	125	Crushing.	Beam buckled badly each side of center.
530	2 x 12	13	Center.	8,030	6,570	.....	255	Shear, tension and crushing.	
531	2 x 12	15	Center.	8,530	8,055	.....	271	Tension.	
534	2 x 12	15	Center.	3,860	3,670	.....	124	Tension.	

Cement Tests.

The tests of cement in tension were made on briquettes of 1 square inch cross section in a machine of a special design, the description of which may be found in the *Brickbuilder*, Vol. 4, No. 12, 1895.

The tests in compression were made on 2″ cubes in an Olsen machine of 50,000 pounds capacity, fitted with special platforms for the purpose, the upper platform having a spherical bearing, which enables it to adjust itself to give as nearly as possible a uniformly distributed load upon the specimen. The results given are the total breaking loads upon the specimens.

The sand tests were made with ordinary building sand, which was sifted through a No. 20 sieve to take out the coarse particles. This does not give nearly as high results as can be obtained by using ground quartz, which is ordinarily used for this purpose. All specimens were set under water, the average temperature of the bath being about 70° F.

SAND TESTS. COMPRESSION.

Date of test.	Kind of cement.	Brand.	Parts of sand to one part cement.	Per cent. of water used in mixing.	Time of set days.	Breaking strength.
Nov. 18, 1895.	Portland.	Commercial American.	3	12	7	2,970
Nov. 18, 1895.	Portland.	Commercial American.	3	12	7	3,100
Dec. 16, 1895.	Portland.	Commercial American.	3	12	7	2,400
Dec. 16, 1895.	Portland.	Commercial American.	3	12	7	2,400
Dec. 16, 1895.	Portland.	Commercial American.	3	12	7	2,450
Dec. 6, 1895.	Portland.	Commercial American.	3	12	23	5,000
Dec. 6, 1895.	Portland.	Commercial American.	3	12	23	5,200
Mar. 18, 1896.	Portland.	Commercial American.	2	10	2	2,570
Mar. 18, 1896.	Portland.	Commercial American.	2	10	2	2,750
Mar. 18, 1896.	Portland.	Commercial American.	2	10	2	2,750
Mar. 18, 1896.	Portland.	Commercial American.	2	10	2	3,100
Mar. 27, 1896.	Portland.	Commercial American.	2	10	4	3,900
Mar. 27, 1896.	Portland.	Commercial American.	2	10	4	4,590
April 1, 1896.	Portland.	Commercial American.	2	10	5	4,760
April 2, 1896.	Portland.	Commercial American.	2	10	6	4,800
April 2, 1896.	Portland.	Commercial American.	2	10	6	5,150
Mar. 11, 1896.	Portland.	Commercial American.	2	10	7	5,450
Mar. 7, 1896.	Portland.	Commercial American.	2	10	7	5,780
Mar. 7, 1896.	Portland.	Commercial American.	2	10	7	5,950
Mar. 16, 1896.	Portland.	Commercial American.	2	10	11	9,390
Mar. 16, 1896.	Portland.	Commercial American.	2	10	11	9,800

SAND TESTS. TENSION.

Date of test.	Kind of cement.	Brand.	Parts of sand to one part cement.	Per cent. of water used in mixing.	Time of set days.	Breaking strength.
Nov. 18, 1895.	Portland.	Commercial American.	3	12	7	90
Dec. 4, 1895.	Portland.	Commercial American.	3	12	7	87
Dec. 4, 1895.	Portland.	Commercial American.	3	12	7	87
Dec. 4, 1895.	Portland.	Commercial American.	3	12	7	90
Dec. 16, 1895.	Portland.	Commercial American.	3	12	7	97
Dec. 16, 1895.	Portland.	Commercial American.	3	12	7	99
Dec. 9, 1895.	Portland.	Commercial American.	3	12	14	106
Dec. 9, 1895.	Portland.	Commercial American.	3	12	14	111
Dec. 6, 1895.	Portland.	Commercial American.	3	12	23	132
Dec. 6, 1895.	Portland.	Commercial American.	3	12	23	141
Mar. 11, 1896.	Portland.	Commercial American.	2	10	7	164
Mar. 11, 1896.	Portland.	Commercial American.	2	10	7	170
April 1, 1896.	Portland.	Commercial American.	2	10	7	160
April 1, 1896.	Portland.	Commercial American.	2	10	7	162
April 1, 1896.	Portland.	Commercial American.	2	10	7	170
April 1, 1896.	Portland.	Commercial American.	2	10	7	176
Mar. 16, 1896.	Portland.	Commercial American.	2	8	11	180
Mar. 16, 1896.	Portland.	Commercial American.	2	8	11	184
Mar. 16, 1896.	Portland.	Commercial American.	2	8	11	200

NEAT CEMENT. COMPRESSION.

Date of test.	Kind of cement.	Brand.	Per cent. of water used in mixing.	Time of set days.	Breaking strength.
Mar. 18, 1896.	Portland.	Commercial American.	25	2	6,750
Mar. 18, 1896.	Portland.	Commercial American.	25	2	6,680
Mar. 27, 1896.	Portland.	Commercial American.	25	4	8,700
Mar. 27, 1896.	Portland.	Commercial American.	25	4	8,770
Mar. 27, 1896.	Portland.	Commercial American.	25	4	8,800
Mar. 27, 1896.	Portland.	Commercial American.	25	4	9,380
Nov. 11, 1895.	Portland.	Commercial American.	26	4	8,450
Nov. 11, 1895.	Portland.	Commercial American.	26	4	8,510
Nov. 15, 1895.	Portland.	Commercial American.	27	7	10,000
Nov. 15, 1895.	Portland.	Commercial American.	27	7	10,200
Nov. 18, 1895.	Portland.	Commercial American.	27	7	10,530
Nov. 18, 1895.	Portland.	Commercial American.	27	7	10,020
Nov. 18, 1895.	Portland.	Commercial American.	27	7	10,150
Dec. 4, 1895.	Portland.	Commercial American.	27	7	10,230
Dec. 4, 1895.	Portland.	Commercial American.	27	7	10,320
Dec. 16, 1895.	Portland.	Commercial American.	27	7	10,000
Dec. 16, 1895.	Portland.	Commercial American.	27	7	10,450
Dec. 13, 1895.	Portland.	Commercial American.	27	7	11,280
Dec. 13, 1895.	Portland.	Commercial American.	27	7	10,960
Dec. 13, 1895.	Portland.	Commercial American.	27	7	10,690
April 3, 1896.	Portland.	Commercial American.	25	7	10,030
April 3, 1896.	Portland.	Commercial American.	25	7	10,350
April 3, 1896.	Portland.	Commercial American.	25	7	11,400
April 1, 1896.	Portland.	Commercial American.	25	7	10,790
April 1, 1896.	Portland.	Commercial American.	25	7	10,620
April 1, 1896.	Portland.	Commercial American.	25	7	10,830
April 1, 1896.	Portland.	Commercial American.	25	7	11,020
Mar. 31, 1896.	Portland.	Commercial American.	25	7	10,550
Mar. 13, 1896.	Portland.	Commercial American.	25	7	10,820
Mar. 13, 1896.	Portland.	Commercial American.	25	7	10,900
Mar. 13, 1896.	Portland.	Commercial American.	25	7	11,350
Mar. 11, 1896.	Portland.	Commercial American.	25	7	11,320
Mar. 11, 1896.	Portland.	Commercial American.	25	7	10,780
Mar. 11, 1896.	Portland.	Commercial American.	25	7	11,280
Nov. 20, 1895.	Portland.	Commercial American.	27	8	10,500
Nov. 20, 1895.	Portland.	Commercial American.	27	8	10,540
Nov. 20, 1895.	Portland.	Commercial American.	27	8	10,590
Dec. 13, 1895.	Portland.	Commercial American.	27	8	10,600
Dec. 13, 1895.	Portland.	Commercial American.	27	8	10,700
Nov. 15, 1895.	Portland.	Commercial American.	26	9	11,100
Nov. 15, 1895.	Portland.	Commercial American.	26	9	11,350
Nov. 15, 1895.	Portland.	Commercial American.	25	10	11,720
Nov. 15, 1895.	Portland.	Commercial American.	25	10	11,910
Dec. 7, 1895.	Portland.	Commercial American.	27	11	11,900
Dec. 7, 1895.	Portland.	Commercial American.	27	11	11,900
Dec. 6, 1895.	Portland.	Commercial American.	27	14	13,500
Dec. 6, 1895.	Portland.	Commercial American.	27	14	13,550
Dec. 6, 1895.	Portland.	Commercial American.	27	14	13,420
Dec. 6, 1895.	Portland.	Commercial American.	27	23	16,050
Dec. 6, 1895.	Portland.	Commercial American.	27	23	15,990
Dec. 6, 1895.	Portland.	Commercial American.	27	23	15,800
Nov. 1, 1895.	Portland.	B. S. & Co.	25	11	15,420
Nov. 1, 1895.	Portland.	B. S. & Co.	25	11	14,860
Mar. 22, 1895.	Portland.	Alsen.	28	2	7,580
Mar. 22, 1895.	Portland.	Alsen.	28	2	7,750
Mar. 22, 1895.	Portland.	Alsen.	28	2	8,130
Mar. 20, 1895.	Portland.	Alsen.	29	33	15,700
Nov. 18, 1895.	Portland.	Alsen.	29	276	37,750

NEAT CEMENT. TENSION.

Date of test.	Kind of cement.	Brand.	Per cent. of water used in mixing.	Time of set days.	Breaking strength.
Mar. 18, 1896.	Portland.	Commercial American.	25	2	270
Mar. 18, 1896.	Portland.	Commercial American.	25	2	270
Mar. 18, 1896.	Portland.	Commercial American.	25	2	288
Mar. 27, 1896.	Portland.	Commercial American.	25	4	344
Nov. 11, 1895.	Portland.	Commercial American.	26	4	340
Nov. 11, 1895.	Portland.	Commercial American.	26	4	345
Nov. 11, 1895.	Portland.	Commercial American.	26	4	369
Nov. 14, 1895.	Portland.	Commercial American.	27	6	370
Nov. 14, 1895.	Portland.	Commercial American.	27	6	371
Nov. 14, 1895.	Portland.	Commercial American.	27	6	372
Nov. 14, 1895.	Portland.	Commercial American.	27	6	390
April 2, 1896.	Portland.	Commercial American.	25	6	389
April 2, 1896.	Portland.	Commercial American.	25	6	389
Nov. 12, 1895.	Portland.	Commercial American.	25	7	415
Nov. 12, 1895.	Portland.	Commercial American.	25	7	440
Nov. 18, 1895.	Portland.	Commercial American.	27	7	412
Dec. 4, 1895.	Portland.	Commercial American.	27	7	414
Dec. 4, 1895.	Portland.	Commercial American.	27	7	470
Dec. 13, 1895.	Portland.	Commercial American.	27	7	400
Dec. 13, 1895.	Portland.	Commercial American.	27	7	405
Dec. 13, 1895.	Portland.	Commercial American.	27	7	410
Dec. 16, 1895.	Portland.	Commercial American.	27	7	412
Dec. 13, 1895.	Portland.	Commercial American.	27	7	420
April 3, 1896.	Portland.	Commercial American.	25	7	400
April 1, 1896.	Portland.	Commercial American.	25	7	434
Mar. 31, 1896.	Portland.	Commercial American.	25	7	438
April 1, 1896.	Portland.	Commercial American.	25	7	449
April 1, 1896.	Portland.	Commercial American.	25	7	451
April 1, 1896.	Portland.	Commercial American.	25	7	458
Mar. 11, 1896.	Portland.	Commercial American.	25	7	442
Mar. 11, 1896.	Portland.	Commercial American.	25	7	444
Dec. 13, 1895.	Portland.	Commercial American.	27	9	456
Mar. 13, 1896.	Portland.	Commercial American.	25	9	478
Mar. 13, 1896.	Portland.	Commercial American.	25	9	498
Mar. 16, 1896.	Portland.	Commercial American.	25	11	504
Dec. 6, 1895.	Portland.	Commercial American.	27	14	513
Dec. 6, 1895.	Portland.	Commercial American.	27	23	520
Dec. 6, 1895.	Portland.	Commercial American.	27	23	540
Oct. 28, 1895.	Portland.	B. S. & Co.	25	3	382
Oct. 28, 1895.	Portland.	B. S. & Co.	25	3	410
Oct. 28, 1895.	Portland.	B. S. & Co.	25	3	411
Oct. 30, 1895.	Portland.	B. S. & Co.	25	7	470
Oct. 31, 1895.	Portland.	B. S. & Co.	25	7	505
Nov. 15, 1895.	Portland.	B. S. & Co.	25	31	560
Nov. 15, 1895.	Portland.	B. S. & Co.	25	31	564
Nov. 15, 1895.	Portland.	B. S. & Co.	25	31	620
Nov. 18, 1895.	Portland.	B. S. & Co.	25	31	578
Nov. 18, 1895.	Portland.	B. S. & Co.	25	32	616
Nov. 18, 1895.	Portland.	B. S. & Co.	25	32	626
Nov. 18, 1895.	Portland.	B. S. & Co.	25	33	669
Nov. 18, 1895.	Portland.	B. S. & Co.	25	33	686
Dec. 20, 1895.	Portland.	B. S. & Co.	25	63	664
Dec. 20, 1895.	Portland.	B. S. & Co.	25	63	680
Dec. 20, 1895.	Portland.	B. S. & Co.	25	64	706
Dec. 20, 1895.	Portland.	B. S. & Co.	25	65	732
Dec. 20, 1895.	Portland.	B. S. & Co.	28	66	680
Oct. 23, 1895.	Portland.	Alsen.	25	2	418
Oct. 23, 1895.	Portland.	Alsen.	25	2	420
Oct. 23, 1895.	Portland.	Alsen.	25	2	430
Oct. 23, 1895.	Portland.	Alsen.	25	2	460
Oct. 19, 1894.	Portland.	Alsen.	30	6	590
Oct. 19, 1894.	Portland.	Alsen.	30	6	591
Oct. 19, 1894.	Portland.	Alsen.	30	6	600
Nov. 13, 1895.	Portland.	Alsen.	29	271	840
Nov. 13, 1895.	Portland.	Alsen.	29	271	860

Compression of Timber Across the Grain.

These tests were made on the 300,000-pound Emery testing machine.

The specimens were placed between the compression platforms of the machine and the load applied slowly. The platforms were adjusted so as to bear fairly on the two opposite faces of the specimen. It was found that the location of the heart with reference to the stick had considerable influence on the strength, and for this reason the sketches showing time rings were made.

Different sizes of specimens from the same wood were tried. In the larger sizes no maximum load was reached in many cases, the piece simply crushing together. This was to be expected with specimens of large section and of short length between the platforms.

BRIEF SUMMARY OF TESTS ON COMPRESSION OF TIMBER ACROSS THE GRAIN.

Kind of wood.	Approximate size of timber. (In.)	Number of tests.	Average of tests. (Lbs. per sq. in.)	Kind of wood.	Approximate size of timber. (In.)	Number of tests.	Average of tests. (Lbs. per sq. in.)	Kind of wood.	Approximate size of timber. (In.)	Number of tests.	Average of tests. (Lbs. per sq. in.)
Spruce.	2¾ x 10	60	396	Spruce.	4 x 6	5	511	Yellow Pine.	4 x 6	17	566
Spruce.	2 x 12	21	252	Spruce.	4 x 8	10	494	Oak.	4 x 12	60	898
Spruce.	3 x 12	23	350	Spruce.	6 x 8	5	424	Oak.	4 x 12	51	980
Spruce.	4 x 12	59	397	Yellow Pine.	4 x 12	60	535	Oak.	6 x 12	17	835
Spruce.	6 x 12	26	319	Yellow Pine.	6 x 12	16	402	Oak.	8 x 12	21	913
Spruce.	8 x 12	31	350	Yellow Pine.	8 x 12	18	471	Maple.	4 x 12	21	1808
Spruce.	10 x 12	5	664	Yellow Pine.	8 x 8	5	696	Hemlock.	4 x 12	20	330

The column marked "approximate size of timber" gives in the first figure the width of the stick bearing on the platform of the machine.

The second figure gives the distance between the compression platforms, or it corresponds to what would be the depth of the stick.

The length or the distance with the grain was in most cases 13 inches, this being about the limit of width of the platforms of the machine.

2½"x10"			2"x12"			3"			8"x8"		
Section	Dapag's	Max. lbs per sq. in.	Section	Dapag's	Max. lbs per sq. in.	Section	Dapag's	Max. lbs per sq. in.	Section	Dapag's	Max. lbs per sq. in.
	2½"x10"	375		2"x12"	262		3"			8"x8"	
	2½"x10"	508		2"x12"	231		3"			8"x8"	
	2½"x10"	411		2"x12"	193		3"			8"x8"	
	2½"x10"	345		2"x12"	281		3"			8"x8"	
	2½"x10"	281		2"x12"	269		3"			8"x8"	
	2½"x10"	408		2"x12"	222		3"			8"x8"	
	2½"x10"	269		2"x12"	258		3"			8"x8"	
	2½"x10"	315		2"x12"	166		3"			8"x8"	
	2½"x10"	262		2"x12"	272		3"			8"x8"	
	2½"x10"	316		2"x12"	226		3"			8"x8"	
	2½"x10"	300		2"x12"	297		3"			8"x8"	
	2½"x10"	400		2"x12"	296		3"			8"x8"	
	2½"x10"	320		2"x12"	358		3"			8"x8"	
	2½"x10"	362		2"x12"	287		3"			8"x8"	
	2½"x10"	255		2"x12"	237		3"			8"x8"	
	2½"x10"	294		2"x12"	269		3"				
	2½"x10"	214		2"x12"	213		3"				
	2½"x10"	248		2"x12"	298		3"				
	2½"x10"	360		2"x12"	203		3"				
	2½"x10"	320		2"x12"	175		3"				
	2½"x10"	325		2"x12"	281		3"				
	2½"x10"	381					3"				
	2½"x10"	461					3"				
	2½"x10"	442									
	2½"x10"	399									
	2½"x10"	364									
	2½"x10"	456									
	2½"x10"	316									
	2½"x10"	436									
	2½"x10"	416									
	2½"x10"	372									
	2½"x10"	417									
	2½"x10"	428									
	2½"x10"	448									
	2½"x10"	538									
	2½"x10"	383									
	2½"x10"	313									
	2½"x10"	474									
	2½"x10"	473									
	2½"x10"	355									
	2½"x10"	377									
	2½"x10"	302									
	2½"x10"	383									
	2½"x10"	831									
	2½"x10"	490									
	2½"x10"	536									
	2½"x10"	380									
	2½"x10"	440									
	2½"x10"	464									
	2½"x10"	440									
	2½"x10"	697									
	2½"x10"	400									
	2½"x10"	695									
	2½"x10"	604									
	2½"x10"	465									
	2½"x10"	461									
	2½"x10"	408									
	2½"x10"	289									
	2½"x10"	500									
	2½"x10"	431									

TENSION TESTS

TENSION TESTS.

Date.	Specimen.	Dimensions of cross section. (Inches.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)
1895.							
Oct. 21	Refined iron.	.76 diameter.	.454	10.00	... .	.....	.....
Oct. 23	Refined iron.	.77 diameter.	.466	10.00	500 to 6,500	.0048	26,800,000
Oct. 25	Refined iron.	.75 diameter.	.442	10.00	500 to 6,500	.0050	27,200,000
Oct. 26	Refined iron.	.75 diameter.	.442	10.00	500 to 6,500	.0052	26,100,000
Oct. 28	Refined iron.	.76 diameter.	.454	10.00	500 to 6,500	.0056	26,000,000
Oct. 31	Refined iron.	4.00 × 1.01	4.04	14.00	... .	.....	.....
Nov. 4	Refined iron.	.76 diameter.	.454	11.00	... .	.....	.....
Nov. 4	Refined iron.	.76 diameter.	.454	11.00	500 to 6,500	.0047	31,000,000
Nov. 4	Wrought iron.	4.00 × 1.00	4.00	25.00	... .	.....	.....
Nov. 6	Refined iron.	.75 diameter.	.442	11.00	500 to 6,500	.0052	28,700,000
Nov. 7	Refined iron.	.76 diameter.	.454	11.00	... .	.....	.....
Nov. 12	Bessemer steel.	.76 diameter.	.454	11.00	500 to 6,500	.0046	31,600,000
Nov. 13	Bessemer steel.	.76 diameter.	.454	11.00	... .	.....	.....
Nov. 14	Wrought iron, Burden's Best.	.76 diameter.	.454	11.00	500 to 6,500	.0046	31,600,000
Nov. 15	Wrought iron, Burden's Best.	.75 diameter.	.442	11.00	500 to 6,500	.0052	28,700,000
Nov. 20	Wrought iron, Burden's Best.	.75 diameter.	.442	11.00	500 to 6,500	.0051	29,300,000
Nov. 22	Wrought iron, Burden's Best.	.77 diameter.	.466	11.00	500 to 6,500	.0051	27,800,000
Nov. 25	Wrought iron, Burden's Best.	.76 diameter.	.454	11.00	500 to 6,500	.0049	29,700,000
Nov. 27	Wrought iron, Burden's Best.	.77 diameter.	.466	11.00	500 to 6,500	.0046	28,200,000
1896.							
Jan. 4	Steel.	2.00 × ½(.0875 + .0890)	.1765	10.00	500 to 12,500	.0232	29,370,000
Jan. 4	Steel.	2.00 × ½(.0960 + .1005)	.1965	10.00	1,500 to 16,500	.0255	29,940,000
Jan. 15	Steel.	2.01 × ½(.0902 + .0912)	.1823	10 00	500 to 10,500	.0190	28,870,000
Jan. 15	Steel.	2.01 × .1015	.2040	10.00	1,500 to 17,500	.0294	26,700,000
Jan. 15	Steel.	2.00 × ½(.0909 + .0908)	.1817	10.00	1,500 to 13,500	.0223	29,620,000
Jan. 15	Steel.	2.00 × .0911	.1822	10.00	500 to 16,500	.0280	29,610,000
Mar. 17	Composition.	.755 diameter.	.448	10.00	500 to 3,500	.0050	13,400,000
Mar. 18	Brass rod.	.756 diameter.	.449	10.00	5,500 to 9,500	.0062	14,300,000
Mar. 23	Brass rod.	.754 diameter.	.446	10.00	500 to 6,500	.0088	15,300,000
Mar. 24	Brass.	.754 diameter.	.446	10.00	500 to 1,500	.0020	11,200,000
Mar. 27	Composition.	1.014 diameter.	.808	10.00	500 to 3,500	.0027	13,700,000
Mar. 30	Steel tape.	.2215 × .0082	.00184	.....	... .	.....	.....
Mar. 31	Steel tape.	.2735 × .0113	.00309	.....	... .	.....	.....
April 2	Aluminum alloy.	1.46 × .53	.774	8.00	500 to 3,500	.0036	8,610,000
May 1	Bronze alloy.	1.54 × .52	.881	6.00	1,000 to 5,000	.0028	10,700,000

TENSION TESTS. — *Continued.*

Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. ins.)	Reduction in area. (Per cent.)	Ultimate extension in gauged length. (Ins.)	Ultimate extension in gauged length. (Per ct.)	Remarks.
11,000	24,200	23,760	52,500	.353	22.3	2.25	22.5	
16,000	34,400	36,000	77,300	.342	26.5	....	....	
15,000	34,000	23,450	53,100	.332	24.9	....	....	
14,000	31,700	23,350	52,900	.322	27.2	....	....	
13,000	28,700	23,400	51,600	.353	22.3	....	....	
.....	.....	164,300	40,700	3.46	14.4	2.25	16.0	
13,000	28,700	24,100	53,100	.342	24.6	2.19	19.9	
15,000	33,100	23,680	52,200	.332	26.9	2.12	19.3	
.....	.....	156,400	39,100	3.47	13.3	2.20	8.8	
14,000	31,700	22,150	50,100	.342	22.6	....	....	Specimen fractured outside measured section.
12,000	26,500	22,400	49,300	.332	26.9	1.47	13.4	
12,000	26,500	22,150	48,800	.132	70.9	3.62	32.9	
13,000	28,700	22,250	49,000	.145	68.0	3.50	31.8	
12,000	26,500	22,450	49,500	.204	55.0	3.50	31.8	
12,000	27,200	21,400	48,400	.237	46.2	3.00	27.3	
12,000	27,200	21,050	47,600	.221	50.1	3.00	27.3	
11,000	23,600	22,000	47,200	.204	56.1	3.31	30.1	
11,000	24,200	21,200	46,700	.264	41.8	3.06	27.8	
11,000	23,600	21,280	45,600	.212	54.5	3.44	31.3	
16,500	93,500	27,480	155,700	.1435	18.7	.87	8.7	
18,000	91,600	27,720	141,100	.1522	22.5	1.12	11.2	
15,500	85,000	22,490	123,400	.1482	18.7	.78	7.8	Covered with dark oxide and curved considerably.
20,500	100,500	30,550	149,700	.1950	4.4	.06	6.0	Covered with dark oxide and curved considerably.
18,500	101,800	24,500	134,800	.1490	18.0	.78	7.8	Covered with dark oxide and curved considerably.
16,000	88,000	25,380	139,300	.1166	36.0	.62	6.2	
.....	.....	13,200	29,400	.351	21.8	1.28	12.8	Composition: 85% copper, 7% spelter, 8% zinc.
.....	.....	31,650	70,500	.235	47.6	....	....	Fractured outside measured section.
.....	.....	31,333	70,200	.227	49.1	....	....	Specimen fractured in the grips.
.....	.....	10,260	23,000	.358	19.9	....	....	Specimen fractured outside measured section.
.....	.....	23,330	28,900	.601	25.6	....	....	Specimen fractured outside measured section.
.....	.....	450	245,000	....	....	....	....	
.....	.....	782	253,000	....	....	....	....	
.....	.....	4,720	6,100	.759	1.9	None.	....	
.....	.....	11,150	13,900	....	...	.....	....	Specimen fractured outside measured section.

TENSION TEST.

Specimen, Steel. Date, January 4, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Per 500 lbs.	Remarks.
500	.5035	.5034	.4393	.4392	.4714	.....	.....	
5,000	.5165	.5165	.4428	.4428	.4797	.0083	.0009	Broke outside measured section.
5,000	.5304	.5304	.4566	.4567	.4935	.....	.....	
10,000	.5407	.5407	.4659	.4659	.5033	.0098	.0010	
12,500	.5458	.5458	.4709	.4709	.5084	.0051	.0010	
13,000	.5469	.5469	.4721	.4719	.5095	.0011	.0011	
13,500	.5479	.5479	.4729	.4727	.5104	.0009	.0009	
14,000	.5489	.5489	.4736	.4737	.5113	.0009	.0009	
14,500	.5497	.5497	.4738	.4748	.5123	.0010	.0010	
15,000	.5508	.5509	.4758	.4757	.5133	.0010	.0010	
15,500	.5520	.5519	.4768	.4767	.5144	.0011	.0011	
16,000	.5530	.5530	.4779	.4779	.5154	.0010	.0010	
16,500	.5539	.5539	.4787	.4787	.5163	.0009	.0009	
17,000	.5552	.5551	.4800	.4799	.5176	.0013	.0013	
17,500	.5565	.5565	.4812	.4813	.5189	.0013	.0013	
18,000	.5581	.5582	.4830	.4830	.5206	.0017	.0017	
18,500	.5606	.....	.4853	. ...	.5230	.0024	.0024	

Length between clamps . . .	10″	Area of original section; sq. ins.	.1765
Dimensions of cross section . .	$2 \times \frac{1}{2}(.0875 + .089)$″	Elastic limit; lbs. per sq. in.	93,500
Elastic limit	16,500 lbs.	Maximum load; lbs. per sq. in. orig. sect.,	155,700
Maximum load	27,480 lbs.	Area of fractured section; sq. in.	.1435
Dimensions of fractured section .	1.84″ × .078″	Reduction of area of cross section; per cent.,	18.7
Ultimate extension	.875″.	Ultimate extension; per cent.	8.75
Elastic elongation for 12,000 lbs. load equals	.0232″	Modulus of elasticity	29,370,000

TENSION TEST.

Specimen, Steel. Date, January 4, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Per 500 lbs.
1,500	.4361	.4361	.5105	.5105	.4733	.....	.....
1,600	.4620	.4619	.5340	.5341	.4980	.0247	.0009
16,500	.4627	.4628	.5350	.5348	.4988	.0008	.0008
17,000	.4636	.4638	.5358	.5358	.4998	.0010	.0010
17,500	.4646	.4646	.5372	.5371	.5009	.0011	.0011
18,000	.4656	.4654	.5381	.5383	.5019	.0010	.0010
18,500	.4672	.....	.5413	.....	.5043	.0024	.0024

Length between clamps . . .	10″	Area of original section; sq. ins.	.1965
Dimensions of cross section . .	$2 \times \frac{1}{2}(.096 + .1005)$″	Elastic limit; lbs. per sq. in.	91,600
Elastic limit	1,800 lbs.	Maximum load; lbs. per sq. in. orig. sect. .	141,100
Maximum load	27,720 lbs.	Area of fractured section; sq. in.	.1522
Dimensions of fractured section .	1.79″ × .085″	Reduction of area of cross section; per cent.,	22.5
Ultimate extension	1.125″	Ultimate extension; per cent.	11.25
Elastic elongation for 15,000 lbs. load equals	.0255″	Modulus of elasticity	29,940,000

TENSION TEST.

Specimen, Steel. Date, January 15, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Per 500 lbs.	Remarks.
500	.4859	.4858	.5063	.5063	.4960	.....	.....	Covered with dark oxide and curved considerably.
6,500	.4993	.4993	.5062	.5162	.5078	.0117	.0010	
10,500	.5044	.5044	.5257	.5260	.5151	.0073	.0009	
14,500	.5103	.5104	.5350	.5350	.5227	.0076	.0009	
15,500	.5109	.5108	.5384	.5382	.5246	.0019	.0010	
16,000	.5117	.5117	.5407	.5407	.5262	.0016	.0016	
16,500	.5120	.5119	.5431	.5433	.5276	.0014	.0014	Broke outside measured section.
17,000	.5124	.5126	.5453	.5452	.5288	.0012	.0012	
17,500	.5170	.....	.5515	.....	.5343	.0055	.0055	

Length between clamps	10″	Area of original section; sq. ins.	.1823
Dimensions of cross section	2.01 × ½(.0902 + .0912)″	Elastic limit; lbs. per sq. in.	85,000
Elastic limit	15,500 lbs.	Maximum load; lbs. per sq. in. orig. sect.	123,400
Maximum load	22,490 lbs.	Area of fractured section; sq. in.	.1482
Dimensions of fractured sect.,	1.83″ × .081″	Reduction of area of cross section; per cent.,	18.7
Ultimate extension	.78″	Ultimate extension; per cent.	7.8
Elastic elongation for 10,000 lbs. load equals	0.0190″	Modulus of elasticity	28,870,000

TENSION TEST.

Specimen, Steel. Date, January 15, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Per 500 lbs.	Remarks.
1,500	.7266	.7266	.6941	.6941	.7104	.....	.....	
15,500	.7398	.7398	.7315	.7316	.7357	.0253	.0009	Covered with dark oxide and curved considerably.
17,500	.7436	.7437	.7360	.7360	.7398	.0041	.0010	
19,000	.7468	.7468	.7388	.7388	.7428	.0030	.0010	
19,500	.7475	.7476	.7440	.7399	.7438	.0010	.0010	
20,000	.7480	.7480	.7415	.7416	.7448	.0010	.0010	
20,500	.7491	.7489	.7427	.7428	.7459	.0011	.0011	Broke outside measured section.
21,000	.7502	.7502	.7443	.7442	.7472	.0013	.0013	
21,500	.7513	.7512	.7454	.7456	.7484	.0012	.0012	
22,000	.7521	.7521	.7468	.7468	.7495	.0011	.0011	
22,500	.7533	.7534	.7480	.7480	.7507	.0012	.0012	
23,500	.7559	.7561	.7508	.7509	.7534	.0027	.0014	
24,000	.7574	.7573	.7523	.7522	.7548	.0014	.0014	
24,500	.7589	.7587	.7540	.7540	.7564	.0016	.0016	
25,000	.7602	.....	.7558	.....	.7580	.0016	.0016	
25,500	.7618	.....	.7583	.....	.7601	.0021	.0021	

Length between clamps	10″	Area of original section; sq. ins.	.20402
Dimensions of cross section	2.01″ × .1015″	Elastic limit; lbs. per sq. in.	100,500
Elastic limit	20,500 lbs.	Maximum load; lbs. per sq. in. orig. sect.	149,700
Maximum load	30,550 lbs.	Area of fractured section; sq. in.	.19502
Dimensions of fractured section	1.96″ × .0995″	Reduction of area of cross section; per cent.,	4.4
Ultimate extension	.06″	Ultimate extension; per cent.	.6
Elastic elongation for 16,000 lbs. load equals	.0294″	Modulus of elasticity	26,700,000

TENSION TEST.

Specimen, Steel. Date, January 15, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Per 500 lbs.	Remarks.
1,500	.4561	.4559	.5223	.5224	.4892	.....	.....	
13,500	.4836	.4834	.5394	.5394	.5115	.0223	.0009	Covered with dark-colored oxide and curved considerably.
14,500	.4853	.4852	.5413	.5414	.5133	.0018	.0009	
15,000	.4862	.4862	.5422	.5422	.5142	.0009	.0009	
15,500	.4872	.4870	.5432	.5430	.5151	.0009	.0009	
16,000	.4882	.4881	.5442	.5440	.5161	.0010	.0010	
16,500	.4891	.4891	.5452	.5454	.5172	.0011	.0011	
17,500	.4916	.4916	.5469	.5469	.5192	.0020	.0010	
18,000	.4926	.4927	.5478	.5478	.5203	.0011	.0011	
18,500	.4942	.4940	.5483	.5484	.5212	.0009	.0009	
19,000	.4960	.4988	.5496	.5497	.5228	.0016	.0016	
19,500	.4988	.....	.5533	.....	.5261	.0033	.0033	

Length between clamps . . .	10″	Area of original section; sq. ins.	.1817
Dimensions of cross section .	2 × ½(.0909 + .0908)″	Elastic limit; lbs. per sq. in.	101,800
Elastic limit	18,500 lbs.	Maximum load; lbs. per sq. in. orig. sect. .	134,800
Maximum load	24,500 lbs.	Area of fractured section; sq. in.	.1490
Dimensions of fractured section,	1.84″ × .081″	Reduction of area of cross section; per cent.,	18.0
Ultimate extension	.78″	Ultimate extension; per cent.	7.8
Elastic elongation for 12,000 lbs. load equals	.0223″	Modulus of elasticity	29,620,000

TENSION TEST.

Specimen, Steel. Date, January 15, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Per 500 lbs.	Remarks.
500	.4469	.4471	.4924	.4926	.4698	.....	.....	
15,500	.4815	.4813	.5141	.5141	.4978	.0280	.0009	Broke outside measured section.
16,000	.4825	.4823	.5149	.5150	.4987	.0009	.0009	
16,500	.4836	.4837	.5166	.5167	.5002	.0015	.0015	

Length between clamps	10″	Area of original section; sq. ins.	.1822
Dimensions of cross section	2″ × .0911″	Elastic limit; lbs. per sq. in.	88,000
Elastic limit	16,000 lbs.	Maximum load; lbs. per sq. in. orig. sect. .	139,300
Maximum load	35,380 lbs.	Area of fractured section; sq. in.	.1166
Dimensions of fractured section . . .	1.85″ × .063″	Reduction of area of cross section; per cent.,	36.0
Ultimate extension	.625″	Ultimate extension; per cent.	6.25
Elastic elongation for 15,000 lbs. load equals	.0280″	Modulus of elasticity	29,610,000

TENSION TEST.

Specimen, Composition. Date, March 17, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Remarks.
500	.1158	.1157	.1211	.1209	.1184	.....	
3,500	.1223	.1223	.1246	.1245	.1234	.0050	85% copper.
4,500	.1250	.1252	.1261	.1262	.1256	.0022	7% spelter.
5,500	.1302	.1301	.1296	.1295	.1298	.0042	8% zinc.
6,500	.1467	.1465	.1447	.1445	.1456	.0158	

Length between clamps	10″	Area of original section; sq. ins.	.448
Dimension of cross section	.7555″ dia.	Maximum load; lbs. per sq. in. orig. sect.	29,400
Maximum load	13,200 lbs.	Area of fractured section; sq. in.	.351
Dimension of fractured section	.6681″ dia.	Reduction of area of cross section; per cent.,	21.8
Ultimate extension	1.28″	Ultimate extension; per cent.	12.8
Elastic elongation for 3,000 lbs. load equals,	.005″	Modulus of elasticity	13,400,000

TENSION TEST.

Specimen, Brass Rod. Date, March 18, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Differences. Per 1,000 lbs.	Remarks.
500	.1170	.1172	.2781	.2779	.1976	.....	.....	
1,500	.1181	.1181	.2922	.2924	.2052	.0076	.0076	Fractured in holder.
2,500	.1189	.1189	.2940	.2940	.2065	.0013	.0013	
3,500	.1202	.1203	.2954	.2953	.2078	.0013	.0013	
4,500	.1215	.1216	.2972	.2972	.2094	.0016	.0016	
5,500	.1230	.1231	.2990	.2990	.2110	.0016	.0016	
6,500	.1236	.1238	.3000	.3000	.2119	.0009	.0016	
7,000	.1250	.1251	.3007	.3009	.2129	.0010	.....	
7,500	.1256	.1256	.3019	.3019	.2138	.0009	.0019	
8,000	.1263	.1263	.3029	.3028	.2146	.0008	.....	
8,500	.1271	.1271	.3036	.3036	.2154	.0008	.0016	
9,000	.1281	.1280	.3043	.3045	.2163	.0009	.....	
9,500	.1288	.1288	.3055	.3054	.2172	.0009	.0018	
10,000	.1294	.1294	.3058	.3059	.2176	.0004	.....	
10,500	.1299	.1300	.3069	.3069	.2185	.0009	.0013	
11,000	.1307	.....	.3078	. ...	.2192	.0007	.....	
11,500	.1315	.....	.3088	.....	.2202	.0010	.0017	
12,000	.1327	.....	.3096	.....	.2212	.0010	.....	
12,500	.1332	.....	.3101	.....	.2217	.0005	.0015	
13,000	.1339	.....	.3111	.....	.2225	.0008	.....	
13,500	.1348	.....	.3117	.....	.2233	.0008	.0016	
14,000	.1356	.....	.3125	.....	.2241	.0008	.....	
14,500	.1361	.....	.3137	.....	.2246	.0005	.0013	
15,000	.1370	.....	.3140	.....	.2255	.0009	.0018	
16,000	.1384	.....	.3156	.....	.2270	.0015	.0015	
17,000	.1408	.....	.3184	.....	.2296	.0026	.0026	
18,000	.1422	.....	.3203	.....	.2313	.0017	.0017	
19,000	.1442	.....	.3218	.....	.2330	.0017	.0017	
20,000	.1462	.....	.3238	.....	.2350	.0020	.0020	
21,000	.1488	.....	.3257	.....	.2372	.0022	.0023	
22,000	.1509	.....	.3281	.....	.2395	.0023	.0020	
24,000	.1551	.....	.3318	.....	.2435	.0040	.0035	
26,000	.1613	.....	.3396	.....	.2505	.0070	.0027	
28,000	.1683	.....	.3434	.....	.2559	.0054	.0072	
30,000	.1823	.....	.3583	.....	.2703	.0144	.....	

Length between clamps	10″	Area of original section; sq. ins.	.449
Dimension of cross section	.756″ dia.	Maximum load; lbs. per sq. in. orig. sect.	70,500
Maximum load	31,650 lbs.	Area of fractured section; sq. in.	.235
Dimension of fractured section	.5475″ dia.	Reduction of area of cross section; per cent.,	47.6
Elastic elongation from 5,500 to 9,500 lbs. load equals	.006a″	Modulus of elasticity	14,300,000

TENSION TEST.

Specimen, Brass Rod. Date, March 23, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Remarks.
500	.1069	.1067	.3612	.3612	.2340	.....	
3,500	.1112	.1111	.3655	.3656	.2383	.0043	Specimen fractured in holder.
6,500	.1160	.1159	.3696	.3698	.2428	.0045	
500	.1082	.1081	.3600	.3599	.2340	.....	
10,000	.1222	.1223	.3746	.3746	.2484	.....	At 30,000 in. lbs. load the scale beam dropped.
12,000	.1250	.1251	.3781	.3781	.2516	.0032	
14,000	.1286	.1284	.3816	.3814	.2550	.0034	
16,000	.1322	.1321	.3850	.3849	.2585	.0035	
18,000	.1356	.1358	.3895	.3893	.2625	.0040	
20,000	.1401	.1402	.3933	.3932	.2667	.0042	
22,000	.1447	.1445	.3981	.3982	.2714	.0047	
24,000	.1492	.1493	.4025	.4025	.2759	.0045	
26,000	.1553	.1551	.4152	.4152	.2814	.0055	
28,000	.1628	.1627	.4152	.4152	.2890	.0076	

Length between clamps . . . . . 10″
Dimension of cross section . . . . . 0.754″ dia.
Maximum load . . . . . 31,333 lbs.
Dimension of fractured section . . . . .538″ dia.
Elastic elongation for 6,000 lbs. load equals, .0088″

Area of original section; sq. ins. 446
Maximum load; lbs. per sq. in. orig. sect., 70,200
Area of fractured section; sq. in. 227
Reduction of area of cross section; per cent., 49.1
Modulus of elasticity 15,300,000

TENSION TEST.

Specimen, Brass. Date, March 24, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Remarks.
500	.3512	.3511	.1021	.1023	.2267	.....	65 % copper.
1,000	.3536	.3536	.1020	.1018	.2278	.0011	35 % spelter.
1,500	.3543	.3541	.1030	.1032	.2287	.0009	
2,000	.3552	.3552	.1041	.1043	.2297	.0010	Fractured outside measured section.
2,500	.3572	.3571	.1056	.1054	.2316	.0019	
3,000	.3608	.3609	.1095	.1094	.2352	.0036	
3,500	.3695	.3700	.1191	.1188	.2445	.0093	

Length between clamps . . . . . 10″
Dimension of cross section . . . . . .754″ dia.
Maximum load . . . . . 10,260 lbs.
Dimension of fractured section . . . . . .675″ dia.
Elastic elongation for 1,000 lbs. load equals, .0020″

Area of original section; sq. ins. 446
Maximum load; lbs. per sq. in. orig. sect. . 23,000
Area of fractured section; sq. in. 358
Reduction of area of cross section; per cent., 19.9
Modulus of elasticity 11,200,000

TENSION TEST.

Specimen, Composition. Date, March 27, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Remarks.
500	.1510	.1512	.3785	.3786	.2648	.....	85% copper.
1,500	.1520	.1520	.3795	.3793	.2657	.0009	7% spelter.
2,500	.1523	.1525	.3800	.3802	.2662	.0005	8% tin.
3,500	.1540	.1540	.3812	.3810	.2675	.0013	
4,500	.1549	.1549	.3819	.3819	.2684	.0009	Fractured outside measured section.
5,500	.1568	.1570	.3836	.3838	.2703	.0019	
6,500	.1580	.1580	.3848	.3846	.2713	.0010	
7,500	.1590	.1588	.3871	.3870	.2730	.0017	
8,500	.1614	.1612	.3884	.3883	.2748	.0018	
9,500	.1638	.1636	.3890	.3891	.2764	.0016	

Length between clamps	10″	Area of original section; sq. ins.	.808
Dimension of cross section	1.0144″ dia.	Maximum load; lbs. per sq. in. orig. sect.,	28,900
Maximum load	23,330 lbs.	Area of fractured section; sq. in.	.601
Dimension of fractured section	.8750″ dia.	Reduction of area of cross section; per cent.,	25.6
Elastic elongation for 3,000 lbs. load equals,	.0027″	Modulus of elasticity	13,700,000

TENSION TEST.

Specimen, Aluminum Alloy. Date, April 2, 1896.

Loads. Actual.	Per sq. in.	Micrometer Readings. 1	2	1	2	Mean.
500	.1743	.1741	.1540	.1538	.1640	.....
1,000	.1732	.1732	.1554	.1555	.1643	.0003
1,500	.1737	.1735	.1561	.1560	.1648	.0005
2,500	.1731	.1730	.1591	.1590	.1660	.0012
3,500	.1742	.1742	.1607	.1607	.1674	.0014
4,500	.1753	.1753	.1629	.1628	.1691	.0017

Length between clamps	8″	Elastic elongation for 3,000 lbs. load equals,	.0036″
Dimensions of cross section	.53″ x 1.46″	Area of original section; sq. ins.	.774
Maximum load	4,720 lbs.	Maximum load; lbs. per sq. in. orig. sect.,	6,100
Dimensions of fractured section	.52″ x 1.46″	Area of fractured section; sq. in.	.759
Ultimate extension	No apparent extension in 8″	Reduction of area of cross section; per cent.,	1.9
		Modulus of elasticity	8,610,000

TENSION TEST.

Specimen, Bronze Alloy. Date, May 1, 1896.

Loads. Actual.	Micrometer Readings. 1	2	1	2	Mean.	Differences. Actual.	Remarks.
500	.1117	.1117	.1056	.1056	.1086	.....	At 10,600 in. lbs. load the scale beam dropped.
1,000	.1119	.1118	.1058	.1058	.1088	.0002	
2,000	.1130	.1130	.1059	.1060	.1095	.0007	Fractured outside measured section.
3,000	.1139	.1138	.1064	.1064	.1101	.0006	
4,000	.1146	.1147	.1071	.1072	.1109	.0008	
5,000	.1152	.1153	.1080	.1080	.1116	.0007	Specimen was distorted so badly at break that dimensions of fractured section could not be taken.
6,000	.1160	.1158	.1092	.1092	.1125	.0009	
7,000	.1168	.1169	.1108	.1108	.1138	.0013	
8,000	.1182	.1182	.1135	.1136	.1159	.0021	
9,000	.1210	.1210	.1195	.1195	.1202	.0043	

Length between clamps	6″	Area of original section; sq. ins.	.881
Dimensions of cross section	.52″ x 1.54″	Maximum load; lbs. per sq. in. orig. sect.,	13,900
Maximum load	11,150 lbs.	Reduction of area of cross section; per cent.	None apparent.
Elastic elongation for 1,000 to 5,000 lbs. load equals	.0028″	Modulus of elasticity	10,700,000

TENSION TESTS OF WIRE.

TENSION TESTS OF WIRE.

Date.	Specimen.	Diameter. (Inches.)	Area of cross section. (Square inches.)	Gauged length. (Ins.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used in calculation of modulus of elasticity. (Inches.)	Modulus of elasticity. (Lbs. per sq. in.)
1895.							
Oct. 21	Annealed iron wire.	.135	.0143	100.00	.....	.....	.....
Oct. 23	Annealed iron wire.	.136	.0145	100.00	.....	.....	.....
Oct. 23	Annealed iron wire.	.135	.0143	100.00	95 to 190	.0289	23,000,000
Oct. 25	Annealed iron wire.	.136	.0145	100.00	76 to 152	.0205	25,500,000
Oct. 26	Annealed iron wire.	.135	.0143	100.00	95 to 190	.0283	23,500,000
Oct. 28	Annealed iron wire.	.136	.0145	100.00	.....	.....	.....
Oct. 30	Annealed iron wire.	.135	.0143	100.00	.....	.....	.....
Nov. 4	Common iron wire.	.110	.0095	100.00	95 to 190	.0330	30,300,000
Nov. 4	Common iron wire.	.109	.0093	100.00	95 to 190	.0370	27,500,000
Nov. 5	Common iron wire.	.110	.0095	100.00	380 to 532	.0699	22,900,000
Nov. 6	Common iron wire.	.113	.0100	100.00	171 to 247	.0301	25,200,000
Nov. 7	Common iron wire.	.080	.00503	100.00	95 to 190	.0700	27,000,000
Nov. 7	Common iron wire.	.080	.00503	100.00	152 to 247	.0712	26,500,000
Nov. 8	Common iron wire.	.079	.00490	100.00	133 to 247	.0875	26,600,000
Nov. 12	Common iron wire.	.079	.00490	100.00	152 to 304	.1189	26,100,000
Nov. 13	Common iron wire.	.079	.00490	100.00	190 to 247	.0440	26,400,000
Nov. 14	Common iron wire.	.080	.00503	100.00	171 to 209	.0279	27,100,000
Nov. 14	Annealed iron wire.	.081	.00515	100.00	76 to 152	.0554	26,600,000
Nov. 18	Annealed iron wire.	.082	.00528	100.00	.....	.....	.....
Nov. 25	Annealed iron wire.	.082	.00528	100.00	152 to 190	.0266	27,100,000
Nov. 27	Annealed iron wire.	.082	.00528	100.00	152 to 190	.0289	24,900,000
Dec. 5	Annealed iron wire.	.082	.00528	100.00	.....	.....	.....
Dec. 6	Annealed iron wire.	.082	.00528	100.00	152 to 190	.0276	26,100,000
Dec. 6	Annealed iron wire.	.082	.00528	100.00	152 to 190	.0265	27,000,000
Dec. 7	Common iron wire.	.167	.0219	100.00	.....	.....	.....
Dec. 9	Annealed iron wire.	.081	.00515	100.00	.....	.....	.....
Dec. 10	Annealed iron wire.	.082	.00528	100.00	.....	.....	.....
Dec. 12	Common iron wire.	.163	.0209	100.00	.....	.....	.....
Dec. 13	Common iron wire.	.163	.0209	100.00	.....	.....	.....
1896.							
Jan. 16	Piano wire, No. 13.	.0310	.000755	100.00	19 to 38	.0853	29,500,000
Jan. 18	Giese wire, No. 16.	.0356	.000995	100.00	19 to 57	.1293	29,500,000
Jan. 18	Piano wire, No. 22.	.0480	.001810	100.00	38 to 76	.0717	29,300,000
Jan. 18	Giese wire, No. 24.	.0547	.002350	100.00	38 to 114	.1098	29,400,000
Jan. 20	Hard drawn copper wire.	.1045	.00858	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1045	.00858	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1045	.00858	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1045	.00858	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1040	.00849	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1040	.00849	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1042	.00853	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1042	.00853	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1042	.00853	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1042	.00853	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1042	.00853	....	.....	.....	.....
Jan. 20	Hard drawn copper wire.	.1040	.00849	....	.....	.....	.....
Mar. 6	Hard drawn copper wire.	.1047	.00861	100.00	152 to 209	.0446	14,800,000
Mar. 10	Hard drawn copper wire.	.1050	.00866	100.00	152 to 228	.0688	12,800,000
Mar. 11	Hard drawn copper wire.	.1072	.00902	100.00	171 to 247	.0655	13,200,000
Mar. 13	Giese wire.	.0329	.000852	100.00	95 to 152	.2320	28,800,000
Mar. 16	Giese wire.	.0330	.000855	100.00	95 to 171	.2723	24,500,000
Mar. 17	Hard drawn copper wire.	.1048	.00863	100.00	190 to 266	.0831	10,800,000
Mar. 19	Hard drawn copper wire.	.1044	.00856	100.00	190 to 285	.0716	15,500,000
Mar. 20	Soft brass wire.	.072	.00407	100.00	.....	.....	.....
Mar. 27	Bessemer spring wire.	.0911	.00650	100.00	190 to 342	.0952	24,500,000
Mar. 27	Bessemer spring wire.	.0910	.00652	100.00	114 to 304	.1127	25,900,000
Mar. 31	Bessemer spring wire.	.0905	.00645	100.00	380 to 475	.0642	23,000,000
April 1	Bessemer spring wire.	.0911	.00652	100.00	190 to 380	.1206	24,200,000
April 2	Bessemer spring wire.	.0905	.00645	100.00	114 to 342	.1377	25,400,000

TENSION TESTS OF WIRE. — *Continued.*

Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. in.)	Reduction in area. (Per cent.)	Remarks.	Date.
							1895.
627	43,800	1,007	70,400	.00528	63.1		Oct. 21
...	.....	893	61,500	.00363	75.0		Oct. 23
570	39,800	874	61,100	.00724	49.4		Oct. 23
570	39,200	865	59,500	.00419	71.2		Oct. 25
513	35,800	646	45,100	.00332	76 8		Oct. 26
494	34,000	868	59,800	.00396	72.7		Oct. 28
...	.....	893	62,400	.00608	57.5		Oct. 30
608	64,000	864	90,900	.00454	52.3		Nov. 4
...	.....	959	103,000	.00332	64.4		Nov. 4
570	60,000	988	104,000	.00466	51.0		Nov. 5
684	68,200	940	93,700	.00396	60.5		Nov. 6
230	45,800	570	113,000	.00292	41.9		Nov. 7
285	56,700	570	113,000	.00246	51.0		Nov. 7
266	54,300	551	112,000	.00229	53.3		Nov. 8
361	73,600	589	120,000	.00353	28.1		Nov. 12
266	54,300	532	109,000	.00292	40.4		Nov. 13
..	.....	494	98,300	.00283	43.8		Nov. 14
...	.....	513	99,600	.00196	61.9		Nov. 14
266	50,400	494	93,500	.00189	64.3		Nov. 18
266	50,400	456	86,300	.00166	68.5		Nov. 25
285	54,000	475	89,900	.00255	51.7		Nov. 27
304	57,600	513	97,100	.00238	55.0	Fractured at lower grip.	Dec. 5
209	39,600	494	93,500	.00181	65.7	Fractured at lower grip.	Dec. 6
266	50,400	375	71,000	.00173	67.1	Fractured at lower grip.	Dec. 6
988	45,100	1,254	57,200	.00754	65.6	Fractured at lower grip.	Dec. 7
285	55,300	494	95,900	.00204	60.4		Dec. 9
228	43,200	494	93,500	.00132	75.0	Fractured at lower grip.	Dec. 10
836	40,100	1,406	67,400	.00899	56.9		Dec. 12
988	47,300	1,283	61,500	.00985	52.8	Fractured at lower grip.	Dec. 13
							1896.
...	.....	260	345,000	.....	....		Jan. 16
. .	.....	294	296,000	.....	....		Jan. 18
...	.....	475	262,500	.....	....		Jan. 18
...	.....	670	285,030	.....	....		Jan. 18
...	.. ...	494	57,600	.....	....		Jan. 20
..	.....	494	57,600	.....	....		Jan. 20
...	.....	504	58,800	.....	....		Jan. 20
...	.....	513	59,800	.....	....		Jan. 20
...	.....	508	59,800	.....	....		Jan. 20
...	.....	504	59,300	.....	....		Jan. 20
...	.....	508	59,600	.....	....		Jan. 20
...	.....	513	60,200	.....	....		Jan. 20
...	.....	527	61,800	.....	....		Jan. 20
...	.....	508	59,600	.....	....		Jan. 20
...	.....	513	60,200	.....	....		Jan. 20
...	.....	499	58,700	.....	....		Jan. 20
456	53,000	532	61,800	.00427	50.5	Straight grip at upper end, round grip at lower end.	Mar. 6
304	35,100	494	57,100	.00442	49.0	Straight grip at upper end, round grip at lower end. Fractured at lower grip.	Mar. 10
304	33,700	532	58,900	.00604	33.1	Straight grip at each end. Fractured at lower grip.	Mar. 11
...	.....	285	334,000	.....	....		Mar. 13
...	.....	294	344,000	.....	....	Specimen contained soldered splice 3 inches long. It did not fracture at splice.	Mar. 16
418	48,500	437	50,700	.00455	47.3		Mar. 17
...	.....	513	59,900	.00353	58.8		Mar. 19
..	.....	223	54,800	.000940	76.9		Mar. 20
494	76,000	950	146,000	.00425	34.6		Mar. 27
456	69,900	974	149,000	.00316	51.6	Fractured at lower grip.	Mar. 27
513	79,600	969	150,000	.00374	42.0		Mar. 31
475	72,900	950	146,000	.00407	37.5	Fractured at lower grip.	April 1
...	.....	931	143,000	.00394	39.6	Fractured at lower grip.	April 2

TENSION TEST.

Specimen, No. 13 Piano Wire. Date, January 16, 1896.

Loads. Actual.	Micrometer Readings.	Differences. Actual.	Differences. Per 9.5 lbs.	Loads. Actual.	Micrometer Readings.	Differences. Actual.	Differences. Per 9.5 lbs.
19.0	.8823	....	....	123.5	.3965	.0465	.0465
38.0	.7970	.0853	.0427	133.0	.3495	.0470	.0470
57.0	.7113	.0857	.0428	142.5	.3000	.0495	.0495
76.0	.6247	.0866	.0433	152.0	.2484	.0516	.0516
85.5	.5808	.0439	.0439	161.5	.1972	.0512	.0512
95.0	.5357	.0451	.0451	171.0	.1452	.0520	.0520
104.5	.4895	.0462	.0462	180.5	.0922	.0530	.0530
114.0	.4430	.0465	.0465	190.0	.0350	.0572	.0572

Length between clamps . . . . . 100″
Dimension of cross section . . . . . .0310″ dia.
Maximum load . . . . . 260.3 lbs.
Elastic elongation for 19 to 38 lbs. load equals . . . . . .0853″

Area of origiual section; sq. ins. 000755
Maximum load; lbs. per sq. in. orig. sect., 344,900
Modulus of elasticity 29,510,000

TENSION TEST.

Specimen, No. 16 Giese Wire. Date, January 18, 1896.

Loads. Actual.	Micrometer Readings.	Differences. Actual.	Differences. Per 9.5 lbs.	Loads. Actual.	Micrometer Readings.	Differences. Actual.	Differences. Per 9.5 lbs.
19.0	.8138	....	....	152.0	.3496	.0349	.0349
57.0	.6845	.1293	.0323	161.5	.3141	.0355	.0355
66.5	.6520	.0325	.0325	171.0	.2776	.0365	.0365
76.0	.6194	.0326	.0326	180.5	.2407	.0369	.0369
85.5	.5870	.0324	.0324	190.0	.2025	.0382	.0382
95.0	.5536	.0334	.0334	199.5	.1637	.0388	.0388
104.5	.5199	.0337	.0337	209.0	.1230	.0407	.0407
114.0	.4867	.0332	.0332	218.5	.0809	.0421	.0421
123.5	.4529	.0338	.0338	228 0	.0370	.0439	.0439
133.0	.4185	.0344	.0344	232.75	.0115	.0255	.0510
142.5	.3845	.0340	.0340				

Length between clamps . . . . . 100″
Dimension of cross section . . . . . .0356″ dia.
Maximum load . . . . . 294.5 lbs.
Elastic elongation for 19 to 57 lbs. load equals . . . . . .1293″

Area of original section; sq. ins. 00099538
Maximum load; lbs. per sq. in. orig. sect., 295,860
Modulus of elasticity 29,525,000

TENSION TEST.

Specimen, No. 22 Piano Wire. Date, January 16, 1896.

Loads. Actual.	Micrometer Readings.	Differences. Actual.	Differences. Per 9.5 lbs.	Loads. Actual.	Micrometer Readings.	Differences. Actual.	Differences. Per 9.5 lbs.
38.0	.8961	....	....	266.0	.4334	Reset microm.	
76.0	.8244	.0717	.0179				
114.0	.7518	.0726	.0181	275.5	.4128	.0206	.0206
161.5	.6588	.0930	.0186	285.0	.3912	.0216	.0216
180.5	.6204	.0384	.0192	294.5	.3686	.0226	.0226
190.0	.6010	.0194	.0194	304.0	.3447	.0239	.0239
199.5	.5813	.0197	.0197	313.5	.3211	.0236	.0236
209.0	.5614	.0199	.0199	323.0	.2975	.0236	.0236
218.5	.5410	.0204	.0204	332.5	.2730	.0245	.0245
228.0	.5206	.0204	.0204	342.0	.2484	.0246	.0246
237.5	.5000	.0206	.0206	361.0	.1966	.0518	.0259
247.0	.4792	.0208	.0208	380.0	.1388	.0578	.0289
256.5	.4581	.0211	.0211				

Length between clamps . . . . . 100″
Dimension of cross section . . . . . .0480″ dia.
Maximum load . . . . . 475 lbs.
Elastic elongation for 38 to 76 lbs. load equals . . . . . .0717″

Area of original section; sq. ins. 001810
Maximum load; lbs. per sq. in. orig. sect., 262,500
Modulus of elasticity 29,290,000

TENSION TEST.

Specimen, No. 24 Giese Wire. Date, January 18, 1896.

Loads. Actual.	Micrometer Readings.	Differences. Actual, for each increase of load.	Differences. Total from first reading.	Differences. Elastic difference.	Differences. Elastic difference per 9.5 lbs.	Differences. Permanent set.
38.0	.8533					
114.0	.7431	.1102	.1102			
38.0	.8529			.1098	.0137	.0004
190.0	.6328	.1103	.2205			
38.0	.8512			.2184	.0137	.0021
266.0	.5174	.1154	.3359			
38.0	.8448			.3274	.0136	.0085
342.0	.3939	.1235	.4594			
38.0	.8334			.4395	.0137	.0199
418.0	.2620	.1319	.5913			
38.0	.8144			.5524	.0138	.0389
456.0	.1912	.0708	.6621			
494.0	.1087	.0825	.7446			

Length between clamps . . . . . 100″
Dimension of cross section . . . . . .0547″ dia.
Maximum load . . . . . 663.8 lbs.

Area of original section; sq. ins. 0023500
Maximum load; lbs. per sq. in. orig. sect., 285,030
Modulus of elasticity 29,347,000
Special modulus of elasticity between 38 and 114 lbs. 29,454,000

TENSION TEST.

Specimen, Giese Wire. Date, March 13, 1896.

Loads. Actual.	Micrometer Readings. 1	2	Mean.	Differences. Actual.	Remarks.
95	.8706	.8706	.8706	.....	
114	.7948	.7946	.7947	.0759	Fractured 1¼″ from lower holder.
133	.7174	.7173	.7174	.0773	
152	.6386	.6386	.6386	.0788	
171	.5005	.5006	.5006	.1380	
190	.4603	.4603	.4603	.0403	
209	.3594	.3594	.3594	.1009	
228	.2573	.2573	.2573	.1021	

Length between clamps . . . . . 100″
Dimension of cross section . . . . . .0329″ dia.
Maximum load . . . . . 285 lbs.
Elastic elongation for 57 lbs. load equals . .2320″

Area of original section; sq. ins. 000852
Maximum load; lbs. per sq. in. orig. sect., 334,000
Modulus of elasticity 28,800,000

TENSION TEST.

Specimen, Giese Wire. Date, March 16, 1896.

Loads. Actual.	Micrometer Readings. 1	2	Mean.	Differences. Actual.	Remarks.
57	.8573	.8574	.85735	.....	
76	.7988	.7990	.79890	.05845	Soldered splice 3″ long.
95	.6882	.6884	.68830	.11060	
114	.5952	.5952	.59520	.09310	
133	.5055	.5050	.50525	.08995	Did not fail at splice.
152	.4161	.4159	.4160	.08925	
171	.3205	.3204	.32045	.09555	The increase in the stretch at 95 lbs. load
190	.2206	.2208	.2207	.09975	is probably due to splice drawing tight.

Length between clamps . . . . . 100″
Dimension of cross section . . . . . .033″ dia.
Maximum load . . . . . 294.5 lbs.

Area of original section; sq. ins. 000855
Maximum load; lbs. per. sq. in. orig. sect., 344,000

Torsion Machine.

A description of the machine upon which these tests were made will be found in Vol. VI, No. 4, of the *Technology Quarterly.* Since the publication of that description, the measuring apparatus, which proved unsatisfactory, has been replaced by the following:

Two telescopes mounted on cast-iron frames are clamped to the specimen, one at each end of the measured section, and focused on two vertical scales placed 500 inches from the axis of the specimen, measured in a line perpendicular to it at each telescope. The scales are graduated to tenths of an inch from a zero below the level of the axis of the specimen. The reading of the level of the center of the specimen on each scale was carefully determined once for all.

The angle which the axis of the telescope makes with the horizontal $= \tan^{-1} \{$reading of telescope on scale $-$ (reading of level of center of specimen on scale $+$ height of center of telescope above center of specimen)$\} \div 500$.

With the initial load on the specimen, the telescopes are set to read at the tops of the scales. Check readings are taken on each telescope. The mean of each pair of check readings, corrected by subtracting the difference in height between the center of the telescope and the zero of the scale, gives the ordinate of the tangent of the angle which the axis of the telescope makes with the horizontal. The angle itself is found from a table of natural tangents and recorded on the log. This operation is repeated at every load. Then the difference between each two successive angles of each telescope with the horizontal is the angle through which the telescope moves under each increment of load, while the difference between the angle through which the power end telescope moves under an increment of load and the angle through which the scale end telescope moves under that increment is the angle of twist of the specimen in its gauged length.

The maximum angle of each telescope with the horizontal is about 9° 30′ when it is reading on the top of the scale. When it has turned down to an angle of from 2° to 5°, it must be reset to read on the top of the scale again, as other apparatus in the room prevents lower readings. The errors of this apparatus have been carefully determined and found to be insignificant within the limit of accuracy kept in the angles, which are recorded to the nearest ten seconds.

The spring balance which was formerly used to weigh the moment

of twist of the specimen has been replaced by a scale beam graduated directly in inch pounds, and reading to 90 inch pounds by actual division. As these smallest divisions are about $\frac{1}{8}$ inch in length, however, the load can be weighed by estimation with greater precision than 90 inch pounds. The tests of small specimens and of wire were made on a similar machine mounted on the bed of a lathe. The weighing beam of this machine is graduated so that it is possible to weigh twisting moments to one tenth of an inch pound.

TORSION TESTS ON WIRE.

Date.	Specimen.	Diameter of specimen. (Inches.)	Length of specimen between jaws. (Inches.)	Maximum twisting moment. (Inch pounds.)	Apparent outside fiber stress, calculated from max. twisting moment. (Lbs. per. sq. in.)	Turns of specimen between jaws at fracture.	Average turns per inch at fracture.	Remarks.
1896.								
Mar. 6	Hard drawn copper wire.	.0141	12.00	9.4	42,600	70.75	5.90	
Mar. 10	Hard drawn copper wire.	.1050	12.00	14.0	61,600	87.50	7.29	
Mar. 10	Common iron wire.	.194	12.00	108.4	75,600	23.00	1.92	Twisted in sections from $\frac{1}{2}$ in. to 4 in. long, and separated by sharply defined lines, alternately twisted closely and almost straight. No twisted section was more than 1 in. long.
Mar. 13	Common iron wire.	.193	12.00	112.5	81,000	5.00	0.42	
Mar. 16	Common iron wire.	.193	24.00	113.8	80,600	90.50	3.77	
Mar. 19	Spring brass wire.	.0831	12.00	11.3	104,000	5.00	0.42	
Mar. 19	Spring brass wire.	.0830	12.00	10.0	92,400	4.00	0.33	
Mar. 19	Spring brass wire.	.0830	12.00	13.0	120,000	7.75	0.65	
Mar. 25	Bessemer spring wire.	.0910	12.00	23.0	161,000	5.25	0.44	Specimen buckled badly and twisted only at scale end grip.
Mar. 26	Bessemer spring wire.	.0900	12.00	21.5	150,000	4.75	0.40	Specimen buckled badly and twisted only at scale end grip.
Mar. 27	Bessemer spring wire.	.0912	6.00	27.8	187,000	5.00	0.83	
Mar. 27	Bessemer spring wire.	.0912	6.00	25.9	174,000	11.50	1.92	
Mar. 30	Bessemer spring wire.	.0910	6.00	26.5	179,000	4.25	0.71	
Mar. 30	Bessemer spring wire.	.0908	6.00	26.1	178,000	11.50	1.92	
April 1	Bessemer spring wire.	.0908	6.00	24.5	170,000	17.00	2.83	
April 2	Bessemer spring wire.	.0905	6.00	20.6	142,000	7.50	1.25	
April 4	Bessemer spring wire.	.0910	6.00	26.0	176,000	9.00	1.50	
April 4	Bessemer spring wire.	.0910	6.00	26.0	176,000	8.50	1.42	

TORSION TESTS.

Date.	Specimen.	Diameter. (Inches.)	Distance between grips. (Inches.)	Gauged length. (Ins.)	Elastic limit. (Inch lbs.)	Outside fiber stress at elastic limit. (Lbs. per sq. in.)	Maximum twisting moment. (Inch lbs.)	Apparent outside fiber stress calculated from max. twisting moment. (Lbs. per sq. in.)	Shearing modulus of elasticity. (Lbs. per sq. in.)	No. of turns between grips at fracture.	Turns per foot between grips at fracture.	Time of breaking after passing elastic limit.	Time of one revolution of power end chuck after passing elastic limit.	Location of break.	Remarks.
1895.												h. m.	m. s.		
Oct. 24	Bessemer steel.	1.49	60.0	40.00	.....	.....	43,920	66,280	11,800,000	8.6	1.72	.....	.....	6 in. from power end grip.	
Oct. 25	Bessemer steel.	1.50	58.0	40.00	14,400	21,700	44,640	67,400	11,700,000	13.3	2.75	.....	.....	6 in. from power end grip.	
Oct. 30	Bessemer steel.	1.50	57.5	40.00	17,000	25,600	44,820	67,600	11,900,000	11.5	2.40	.....	.....	At power end grip.	
Nov. 1	Bessemer steel.	1.50	57.6	40.00	17,000	25,600	45,810	69,100	11,900,000	9.9	2.03	.....	.....		
Nov. 4	Bessemer steel.	1.50	59.0	40.00	16,000	24,100	45,450	68,600	11,600,000	10.8	2.20	.....	.....		
Nov. 5	Refined iron.	1.75	61.1	40.00	18,000	17,100	56,150	53,400	11,200,000	7.1	1.39	.....	.....		
Nov. 11	Refined iron.	1.75	64.0	40.00	14,400	13,700	55,350	52,600	11,200,000	8.7	1.63	.....	7, 0	3 in. from scale end grip.	
Nov. 12	Refined iron.	1.72	64.5	40.00	14,400	14,300	45,090	44,900	11,800,000	5.4	1.00	.....	7, 0		
Nov. 13	Refined iron.	1.75	61.0	40.00	14,400	13,700	53,360	50,700	11,500,000	6.1	1.20	.....	.....	13 in. from scale end grip.	
Nov. 18	Swedish iron.	2.01	81.5	60.00	18,000	11,300	83,180	52,200	11,500,000	20.8	3.06	.....	.....	At power end grip.	
Nov. 20	Swedish iron.	2.01	79.0	60.00	23,000	14,400	83,340	52,300	11,600,000	20.7	3.14	2, 30	7, 15	At power end grip.	
Nov. 26	Swedish iron.	2.00	77.5	60.00	19,800	12,600	79,650	50,700	11,400,000	19.1	2.96	2, 15	7, 04	At scale end grip.	
Dec. 2	Swedish iron.	2.01	76.7	60.00	19,800	12,600	82,530	52,500	11,200,000	24.3	3.80	1, 30	3, 45	At power end grip.	
Dec. 5	Swedish iron.	2.00	80.5	60.00	23,400	14,900	84,330	53,700	11,700,000	22.3	3.32	1, 45	.....	At power end grip.	
Dec. 10	Swedish iron.	2.00	75.0	60.00	23,400	14,900	84,960	54,100	11,700,000	18.1	2.90	1, 05	3, 31	12 in. from scale end grip.	
Dec. 13	Refined iron.'	1.75	63.2	40.00	16,200	15,400	57,080	54,200	.....	10.2	1.94	0, 35	2, 53	30 in. from scale end grip.	
Dec. 16	Bessemer steel.	1.50	58.8	40.00	18,000	27,200	44,460	67,100	11,700,000	10.5	2.14	0, 40	3, 35	At power end grip.	
1896.															
Mar. 5	Bessemer steel.	1.50	59.1	40.00	16,200	24,400	45,000	67,900	11,500,000	13.2	2.68	.....	3, 30		
Mar. 10	Bessemer steel.	1.50	58.2	40.00	18,000	27,200	44,920	67,800	11,700,000	10.8	2.22	0, 40	3, 49	At power end grip.	
Mar. 13	Refined iron.	1.74	63.0	40.00	16,200	15,400	55,710	52,900	11,300,000	7.8	1.49	.....	5, 34		
Mar. 19	Composition.	1.52	28.0	20.00	4,500	6,530	23,130	33,500	4,810,000	3.6	1.54	1, 0	17, 08	8 in. from power end grip.	85% copper, 7% spelter, 8% tin.
Mar. 23	Composition.	1.51	27.0	20.00	5,040	7,460	28,800	42,600	5,210,000	5.0	2.22	1, 12	14, 20	At power end grip.	
Mar. 25	Brass.	1.51	28.0	20.00	3,600	5,220	17,460	25,900	4,380,000	3.5	1.50	0, 48	13, 43	Center.	
Mar. 26	Bessemer steel.	1.50	58.0	40.00	18,000	27,200	45,540	68,700	11,700,000	11.4	2.36	0, 50	4, 23	At power end grip.	
Mar. 27	Swedish iron.	2.02	79.0	60.00	23,400	14,300	82,350	50,400	11,300,000	21.0	3.19	2, 16	6, 29	At power end grip.	

TORSION TEST.

Specimen, Bessemer Steel. Date, October, 24, 1895.

Twisting moment.	Scale Readings. Power end. 1	2	Scale end. 1	2	Corrected Mean. Power end.	Scale end.	Angles Corresponding. Power end. ° ′ ″	Scale end. ° ′ ″	Differences. Power end. ° ′ ″	Scale end. ° ′ ″	Angle of twist. ° ′ ″	Remarks.
1,800	92.49	92.50	91.48	91.49	83.49	83.58	9, 28, 50	9, 29, 26	.....	.....	.....	
2,700	86.15	86.18	88.22	88.24	77.16	80.31	8, 46, 34	9, 7, 30	0, 42, 16	0, 21, 56	0, 20, 20	
3,600	78.08	78.09	83.29	83.31	69.08	75.40	7, 52, 0	8, 34, 32	0, 54, 34	0, 32, 58	0, 21, 36	
4,500	69.81	69.81	78.30	78.31	60.81	70.40	6, 56, 4	8, 0, 54	0, 55, 56	0, 34, 38	0, 21, 18	Specimen fractured 6″ from power end grip.
5,400	62.50	62.51	73.95	73.93	53.50	66.04	6, 6, 28	7, 31, 26	0, 49, 36	0, 29, 28	0, 20, 8	
6,300	54.80	54.80	68.99	69.00	45.80	61.09	5, 14, 2	6, 58, 0	0, 52, 26	0, 33, 26	0, 19, 0	
7,200	46.21	46.21	63.70	63.71	37.21	55.80	4, 15, 22	6, 22, 6	0, 59, 40	0, 35, 54	0, 23, 46	
7,200	92.87	92.88	93.05	93.03	83.87	85.14	9, 31, 22	9, 39, 48	.....	.....	.....	
8,100	86.58	86.59	89.51	89.51	77.58	81.61	8, 49, 12	9, 16, 12	0, 42, 10	0, 23, 36	0, 18, 34	
9,900	72.28	72.27	81.60	81.60	63.27	73.70	7, 12, 44	8, 23, 61	1, 37, 28	0, 53, 6	0. 44, 22	
11,700	59.08	59.08	74.59	74.60	50.08	66.69	5, 43, 10	7, 35, 52	1, 29, 34	0, 47, 14	0, 42, 20	
13,500	46.08	46.10	67.60	67.61	37.09	59.70	4, 14, 12	6, 48, 34	1, 28, 58	0, 47, 18	0, 41, 40	
15,300	33.39	33.41	60.90	65.90	24.40	53.00	2, 47, 46	6, 3, 2	1, 26, 26	0, 45, 32	0, 40, 54	
15,300	76.40	76.40	84.00	84.00	67.40	76.10	7, 40, 38	8, 39, 14	.....	.....	.....	
17,100	64.35	64.33	77.81	77.80	55.34	69.90	6, 19, 56	7, 57, 3	1, 20, 42	0, 41, 42	0, 39, 0	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	60.0″
Dimension of cross section	1.49″ dia.
Length of specimen between telescopes	40.00″
Maximum twisting moment	43,920 in. lbs.
Number of turns of specimen between jaws at fracture	8.6
Outside fiber stress at elastic limit	66,280 lbs. per sq. in.
Angle of twist between 1,800 in. lbs. and 7,200 in. lbs.	2° 6′ 8″
Shearing modulus of elasticity between 1,800 in. lbs. and 7,200 in. lbs.	11,800,000
Average number of turns of specimen per foot at fracture	1.72

TORSION TEST.

Specimen, Bessemer Steel. Date, October 30, 1895.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
2,700	76.75	76.77	80.42	80.41	67.76	72.51	7, 43, 0	8, 15, 30	.....	.....	.....	
3,600	68.04	68.05	74.80	74.80	59.04	66.90	6, 44, 10	7, 37, 20	0, 58, 50	0, 38, 0	0, 20, 50	Specimen fractured at power end jaw.
4,500	57.92	57.94	67.72	67.71	48.93	59.81	5, 35, 20	6, 49, 20	1, 8, 50	0, 48, 0	0, 20, 50	
5,400	49.31	49.33	62.41	62.42	40.32	54.51	4, 36, 40	6, 13, 20	0, 58, 40	0, 36, 0	0, 22, 40	
5,400	93.11	93.11	90.00	90.00	84.11	82.10	9, 33, 0	9, 19, 30	.....	.....	.....	
6,300	85.50	85.52	85.10	85.10	76.51	77.20	8, 42, 0	8, 46, 40	0, 51, 0	0, 32, 50	0, 18, 10	
7,200	76.90	76.90	79.75	79.75	67.90	71.85	7, 44, 0	8, 9, 30	0, 58, 0	0, 37, 10	0, 20, 50	
8,100	69.20	69.18	75.20	75.20	60.18	67.30	6, 51, 50	7, 40, 0	0, 52, 10	0, 29, 30	0, 22, 40	
9,000	60.98	60.96	70.10	70.08	51.97	62.19	5, 58, 0	7, 4, 40	0, 53, 50	0, 35, 20	0, 18, 30	
9,900	52.78	52.80	64.83	64.82	43.79	56.92	5, 0, 20	6, 29, 40	0, 57, 40	0, 35, 0	0, 22, 40	
9,900	92.10	92.10	84.70	84.70	83.10	76.80	9, 26, 10	8, 44, 0	.....	.....	.....	
11,700	79.31	79.31	77.92	77.90	70.31	70.01	8, 0, 20	7, 58, 10	1, 25, 50	0, 45, 50	0, 40, 0	
12,600	72.58	72.60	74.60	74.60	63.59	66.70	7, 14, 50	7, 35, 40	0, 45, 30	0, 22, 30	0, 23, 0	
13,500	66.80	66.80	71.80	71.80	57.80	63.90	6, 35, 40	7, 17, 0	0, 39, 10	0, 18, 40	0, 20, 30	
14,400	60.58	60.60	68.80	68.80	51.59	60.90	5, 52, 30	6, 56, 40	0, 42, 10	0, 20, 20	0, 21, 50	
15,300	54.40	54.40	65.60	65.60	45.40	57.70	5, 11, 20	6, 35, 0	0, 42, 10	0, 21, 40	0, 20, 30	
16,200	48.48	48.51	62.80	62.80	39.49	54.90	4, 31, 0	6, 16, 0	0, 40, 20	0, 19, 0	0, 21, 20	
16,200	92.10	92.10	80.25	80.23	81.10	72.34	9, 12, 50	8, 14, 0	.....	.....	.....	
17,100	85.50	85.50	77.39	77.40	74.50	69.49	8, 28, 30	7, 54, 50	0, 44, 20	0, 19, 10	0, 25, 10	
18,000	60.15	60.15	72.50	72.52	51.15	64.60	5, 50, 30	7, 22, 40	2, 38, 0	0, 32, 10	2, 5, 50	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	57.5″
Dimension of cross section	1.50″ dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	17,000 in. lbs.
Maximum twisting moment	44,820 in. lbs.
Number of turns of specimen between jaws at fracture	11.5
Outside fiber stress at elastic limit	25,600 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	67,600 lbs. per sq. in.
Angle of twist between 3,600 in. lbs. and 9,900 in. lbs.	2° 26′ 20″
Shearing modulus of elasticity between 3,600 in. lbs. and 9,900 in. lbs.	11,900,000
Average number of turns of specimen per foot at fracture	2.40

TORSION TEST.

Specimen, Bessemer Steel. Date, November 1, 1895.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.	
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
1,800	92.00	92.01	91.60	91.60	83.00	83.70	9, 25, 30	9, 30, 10	.. ..	.. ..	.. ..
3,600	71.79	71.80	77.43	77.44	62.79	69.54	7, 9, 30	7, 55, 0	2, 16, 0	1, 35, 10	0, 40, 50
5,400	57.29	57.31	69.14	69.12	48.30	61.23	5, 31, 0	6, 59, 0	1, 38, 30	0, 56, 0	0, 42, 30
5,400	88.70	88.71	90.59	90.59	79.70	82.68	9, 3, 20	9, 23, 20	.. ..	.. ..	.. ..
7,200	73.81	73.80	81.91	81.91	64.80	74.01	7, 23, 0	8, 25, 10	1, 40, 20	0, 58, 10	0, 42, 10

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	57.⅛″
Dimension of cross section	1.50″ dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	17,000 in. lbs.
Maximum twisting moment	45,810 in. lbs.
Number of turns of specimen between jaws at fracture	9.9
Outside fiber stress at elastic limit	25,600 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	69,100 lbs. per sq. in.
Angle of twist between 1,800 in. lbs. and 7,200 in. lbs.	2° 5′ 30″
Shearing modulus of elasticity between 1,800 in. lbs. and 7,200 in. lbs.	11,900,000
Average number of turns of specimen per foot at fracture	2.03

TORSION TEST.

Specimen, Refined Iron. Date, November 5, 1895.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	94.12	94.12	90.11	90.11	86.07	80.96	9, 46, 0	9, 11, 50	.. ..	.. ..	.. ..	
7,200	77.50	77.50	80.59	80.59	69.45	71.44	7, 54, 30	8, 7, 50	1, 51, 30	1, 4, 0	0, 47, 30	At 21,600 in. lbs. load the scale beam dropped.
10,800	58.50	58.50	68.50	68.50	50.45	59.35	5, 45, 40	6, 46, 10	2, 8, 50	1, 21, 40	0, 47, 10	
10,800	93.59	93.59	90.93	90.93	85.54	81.78	9, 42, 30	9, 17, 30	.. ..	.. ..	.. ..	
14,400	76.50	76.50	81.17	81.17	68.45	72.02	7, 47, 40	8, 11, 50	1, 54, 50	1, 5, 40	0, 49, 10	
18,000	56.39	56.39	70.70	70.70	48.34	61.55	5, 31, 20	7, 1, 0	2, 60, 20	1, 10, 50	0, 49, 30	
18,000	93.33	93.33	93.24	93.24	85.28	84.09	9, 40, 50	9, 32, 50	.. ..	.. ..	.. ..	
21,600	.....	.....	.....	.....	.....	.....	.. ..	....	....	....	.. ..	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.25″
Length of specimen between jaws	61.1″
Dimension of cross section	1.75″ dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	18,000 in. lbs.
Maximum twisting moment	56,150 in. lbs.
Number of turns of specimen between jaws at fracture	7.1
Outside fiber stress at elastic limit	17,100 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	53,400 lbs. per sq. in.
Angle of twist between 3,600 in. lbs. and 14,400 in. lbs.	2° 23′ 50″
Shearing modulus of elasticity between 3,600 lbs. and 14,400 in. lbs.	11,200,000
Average number of turns of specimen per foot at fracture	1.39

TORSION TEST.

Specimen, Refined Iron Bar. Date, November 11, 1895.

Twisting moment.	Scale Readings. Power end. 1	2	Scale end. 1	2	Corrected Mean. Power end.	Scale end.	Angles Corresponding. Power end.	Scale end.	Differences. Power end.	Scale end.	Angle of twist.	Remarks.
							° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	93.50	93.49	90.11	90.10	84.35	82.06	9, 34, 30	9, 19, 10	.....	.....	.....	
7,200	70.68	70.69	74.34	74.32	61.54	66.28	7, 1, 0	7,33, 0	2,33,30	1,46, 10	0, 47, 20	At 19,800 in. lbs. load
10,800	51.10	51.09	61.87	61.85	41.95	53.81	4, 47, 40	6, 8,30	2, 13, 20	1,24,30	0, 48, 50	the scale beam dropped.
10,800	94.34	94.34	91.89	91.90	85.19	83.85	9, 40, 10	9, 31, 10	.....	.....	.....	
12,600	85.41	85.40	86.55	86.55	76.26	78.50	8, 40, 20	8, 55, 20	0, 59, 50	0, 35, 50	0, 24, 0	Specimen fractured
14,400	76.10	76.12	81.11	81.10	66.96	73.06	7, 37, 40	8, 18, 50	1, 2, 40	0, 36, 30	0, 26, 10	3″ from scale end jaw.
16,200	65.10	65.12	74.74	74.74	55.96	66.69	6, 23, 10	7, 35, 50	1, 14, 30	0, 43, 0	0, 31, 30	
18,000	51.90	51.90	68.09	68.11	42.75	60.05	4, 53, 10	6, 50, 50	1, 30, 0	0, 45, 0	0, 45, 0	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.25″
Length of specimen between jaws	64.00″
Dimension of cross section	1.75 in. dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	14,400 in. lbs.
Maximum twisting moment	55,350 in. lbs.
Number of turns of specimen between jaws at fracture	8.7
Outside fiber stress at elastic limit	13,700 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	52,600 lbs. per sq. in.
Angle of twist between 3,600 in. lbs. and 12,600 in. lbs.	2° 0′ 10″
Shearing modulus of elasticity between 3,600 in. lbs. and 12,600 in. lbs.	11,200,000
Average number of turns of specimen per foot at fracture	1.63

TORSION TEST.

Specimen, Refined Iron. Date, November 12, 1895.

Twisting moment.	Scale Readings. Power end. 1	2	Scale end. 1	2	Corrected Mean. Power end.	Scale end.	Angles Corresponding. Power end.	Scale end.	Differences. Power end.	Scale end.	Angle of twist.	Remarks.
							° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	89.89	89.89	90.54	90.54	80.74	82.49	9, 10, 10	9, 20, 10	.....	.....	.....	
5,400	79.90	79.90	83.90	83.90	70.75	75.85	8, 2, 10	8, 37, 30	1, 8, 0	0, 42, 40	0, 25, 20	At 19,800 in. lbs.
7,200	68.65	68.65	76.32	76.31	59.50	68.27	6, 47, 10	7, 46, 30	1, 15, 0	0, 51, 00	0, 24, 0	load the scale beam
9,000	58.66	58.66	69.75	69.75	49.51	61.70	5, 39, 20	7, 2, 0	1, 7, 50	0, 44, 30	0, 23, 20	dropped.
10,800	49.07	49.09	63.72	63.70	39.93	55.66	4, 34, 0	6, 21, 10	1, 5, 20	0, 40, 50	0, 24, 30	
12,600	39.61	39.61	57.83	57.83	30.46	49.78	3, 29, 10	5, 41, 10	1, 4, 50	0, 40, 0	0, 24, 50	
12,600	90.14	90.14	89.02	89.02	80.99	80.97	9, 12, 0	9, 11, 50	.....	.....	.....	
14,400	81.51	81.52	84.08	84.08	72.37	76.03	8, 14, 10	8, 38, 30	0, 57, 50	0, 33, 20	0, 24, 30	
16,200	71.13	71.14	78.13	78.11	61.99	70.07	7, 4, 0	7, 58, 40	1, 10, 10	0, 39, 50	0, 30, 20	
18,000	59.60	59.62	71.90	71.90	50.46	63.85	5, 45, 50	7, 16, 40	1, 18, 10	0, 42, 0	0, 36, 10	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90″; scale end, 2.80″
Height of center of telescope above center of test piece	5.25″
Length of specimen between jaws	64.5″
Dimension of cross section	1.72 in. dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	14,400 in. lbs.
Maximum twisting moment	45,090 in. lbs.
Number of turns of specimen between jaws at fracture	5.4
Outside fiber stress at elastic limit	14,300 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	44,900 lbs. per sq. in.
Angle of twist between 3,600 in. lbs. and 12,600 in. lbs.	2° 2′ 0″
Shearing modulus of elasticity between 3,600 in. lbs. and 12,600 in. lbs.	11,800,000
Average number of turns of specimen per foot at fracture	1.00

TORSION TEST.

Specimen, Refined Iron. Date, November 13, 1895.

Twisting moment.	Scale Readings. Power End. 1	Power End. 2	Scale End. 1	Scale End. 2	Corrected Mean. Power End.	Corrected Mean. Scale End.	Angles Corresponding. Power End.	Angles Corresponding. Scale End.	Differences. Power End.	Differences. Scale End.	Angle of Twist.	Remarks.
							° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
1,800	93.23	93.23	89.91	89.92	84.08	81.86	9, 32, 40	9, 17, 50	.....	.....	.. ..	
3,600	84.52	84.54	84.62	84.61	75.38	76.56	8, 34, 20	8, 42, 20	0, 58, 20	0, 35, 30	0, 22, 50	Specimen fractured
5,400	73.62	73.63	77.22	77.20	64.47	69.16	7, 20, 50	7, 52, 30	0, 73, 30	0, 49, 50	0, 23, 40	13″ from power end
7,200	63.83	63.84	70.90	70.90	54.68	62.85	6, 14, 30	7, 9, 50	0, 66, 20	0, 42, 40	0, 23, 40	jaw.
9,000	55.35	55.34	65.93	65.92	46.19	57.87	5, 16, 40	6, 36, 10	0, 57, 50	0, 33, 40	0, 24, 10	
10,800	47.10	47.11	61.12	61.12	37.95	53.07	4, 20, 30	6, 3, 30	0, 56, 10	0, 32, 40	0, 23, 30	
12,600	38.71	38.72	56.21	56.22	29.56	48.16	3, 23, 0	5, 30, 10	0, 57, 30	0, 33, 20	0, 24, 10	
12,600	91.86	91.86	89.40	89.41	82.71	81.35	9, 23, 30	9, 14, 30	.....	.....	.. ..	
14,400	83.70	83.72	84.87	84.88	74.56	76.82	8, 28, 50	8, 44, 10	0, 54, 40	0, 30, 20	0, 24, 20	
16,200	74.70	74.70	80.09	80.07	65.55	72.03	7, 28, 10	8, 11, 50	1, 0, 40	0, 32, 20	0, 28, 20	
18,000	64.32	64.33	75.12	75.14	55.17	67.08	6, 17, 50	7, 38, 30	1, 10, 20	0, 33, 20	0, 37, 0	
19,800	46.67	46.65	68.39	68.41	37.51	60.35	4, 17, 20	6, 53, 0	2, 0, 30	0, 45, 30	1, 15, 0	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90″; scale end, 2.80″
Height of center of telescope above center of test piece	5.25″
Length of specimen between jaws	61.00″
Dimension of cross section	1.75 in. dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	14,400 in. lbs.
Maximum twisting moment	53,360 in. lbs.
Number of turns of specimen between jaws at fracture	6.1
Outside fiber stress at elastic limit	13,700 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	50,700 lbs. per sq. in.
Angle of twist between 1,800 in. lbs. and 10,800 in. lbs.	1° 57′ 10″
Shearing modulus of elasticity between 1,800 in. lbs. and 10,800 in. lbs.	11,500,000
Average number of turns of specimen per foot at fracture	1.20

TORSION TEST.

Specimen, Swedish Iron. Date, November 18, 1895.

Twisting moment.	Scale Readings. Power end. 1	Power end. 2	Scale end. 1	Scale end. 2	Corrected Mean. Power end.	Corrected Mean. Scale end.	Angles Corresponding Power end.	Angles Corresponding Scale end.	Differences. Power end.	Differences. Scale end.	Angle of twist.	Remarks.
							° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	91.21	91.20	86.75	86.76	81.84	78.49	9, 17, 40	8, 55, 20	.....	.....	.. ..	
7,200	73.27	73.27	74.80	74.80	63.91	66.54	7, 17, 0	7, 34, 50	2, 0, 40	1, 20, 30	0, 40, 10	Specimen fractured at
10 800	59 58	59.56	66.97	66.96	50.21	58.70	5, 44, 0	6, 41, 40	1, 33, 0	0, 53, 10	0, 39, 50	power end jaw.
14,400	46.04	46.03	59.31	59 30	36.67	51.04	4, 11, 40	5, 49, 40	1, 32, 20	0, 52, 0	0, 40, 20	
18,000	33.40	33.40	52.56	52.54	24 04	44.29	2, 45, 10	5, 3, 40	1, 26, 30	0, 46, 0	0, 40, 30	
18,000	80.87	80.86	83.33	83.32	71.50	75.06	8, 8, 20	8, 32, 5	.....	.....	.. ..	
21,600	67.68	67.69	78.67	78.68	58.32	74.41	6, 39, 10	8, 27, 50	1, 29, 10	0, 4, 15	1, 24, 55	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.46″
Length of specimen between jaws	81.5″
Dimension of cross section	2.01 in. dia.
Length of specimen between telescopes	60.00″
Elastic limit in torsion	18,000 in. lbs.
Maximum twisting moment	83,180 in. lbs.
Number of turns of specimen between jaws at fracture	20.8
Outside fiber stress at elastic limit	11,300 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	52,200 lbs. per sq. in.
Angle of twist between 3,600 in. lbs. and 14,400 in. lbs.	2° 0′ 20″
Shearing modulus of elasticity between 3,600 in. lbs. and 14,400 in. lbs.	11,500,000
Average number of turns of specimen per foot at fracture	3.06

TORSION TEST.

Specimen, Swedish Iron. Date, November 20, 1895.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	79.72	79.72	76.59	76.61	70.36	68.34	8, 0, 40	7, 47, 0	.....	.....	.....	
7,200	69.99	69.99	72.72	72.70	60.63	64.45	6, 54, 50	7, 20, 40	1, 5, 50	0, 26, 20	0, 39, 30	At 25,200 in. lbs. load
10,800	60.39	60.41	68.98	68.98	51.04	60.72	5, 49, 40	6, 55, 30	1, 5, 10	0, 25, 10	0, 40, 0	the scale beam
14,400	49.71	49.71	64.17	64.19	40.35	55.92	4, 36, 50	6, 23, 0	1, 12, 50	0, 32, 30	0, 40, 20	dropped.
16,200	43.06	43.08	60.46	60.45	33.71	52.20	3, 51, 20	5, 57, 40	0, 45, 30	0, 25, 20	0, 20, 10	
18,000	37.50	37.50	57.76	57.78	28.15	49.51	3, 13, 20	5, 39, 40	0, 38, 0	0, 18, 0	0, 20, 0	Specimen fractured at
18,000	92.90	92.91	84.62	84.64	83.54	76.37	9, 29, 10	8, 41, 0	.....	.....	.....	power end jaw.
19,800	86.91	86.91	81.66	81.66	77.55	73.40	8, 49, 0	8, 21, 0	0, 40, 10	0, 20, 0	0, 20, 10	
21,600	80.99	80.98	78.83	78.83	71.63	70.57	8, 9, 10	8, 2, 0	0, 39, 50	0, 19, 0	0, 20, 50	
23,400	74.60	74.60	75.53	75.52	65 24	67.27	7, 26, 0	7, 39, 50	0, 43, 10	0, 22, 10	0, 21, 0	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.25″
Length of specimen between jaws	79.0″
Dimension of cross section	2.01 in. dia.
Length of specimen between telescopes	60.00″
Elastic limit in torsion	23,000 in. lbs.
Maximum twisting moment	83,340 in. lbs.
Number of turns of specimen between jaws at fracture	20.7
Outside fiber stress at elastic limit	14,400 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	52,300 lbs. per sq. in.
Angle of twist between 3,600 in. lbs. and 18,000 in. lbs.	2° 40′ 0″
Shearing modulus of elasticity between 3,600 in. lbs. and 18,000 in. lbs.	11,600,000
Average number of turns of specimen per foot at fracture	3.14

TORSION TEST.

Specimen, Swedish Iron. Date, November 26, 1895.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding		Differences.		Angle of Twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	92.23	92.24	91.07	91.06	82.87	82.80	9, 24, 40	9, 24, 10	.....	.....	.....	
7,200	72.79	72.79	77.62	77.61	63.43	69.35	7, 13, 48	7, 53, 50	2, 10, 52	1, 30, 20	0, 40, 32	Specimen fractured at
10,800	56.40	56.40	67.19	67.18	47.04	58.92	5, 22, 30	6, 43, 10	1, 51, 18	1, 10, 40	0, 40, 38	scale end jaw.
14,400	41.99	41.98	58.77	58.76	32.62	50.50	3, 44, 0	5, 46, 0	1, 38, 30	0, 57, 10	0, 41, 20	
18,000	28.56	28.56	51.40	51.40	19.20	43.14	2, 12, 0	4, 55, 50	1, 32, 0	0, 50, 10	0, 41, 50	
18,000	89.61	89.61	81.38	81.39	80.25	73.12	9, 7, 10	8, 19, 10	.....	.....	.....	
19,800	83.01	83.01	78.13	78.14	73.65	69.87	8, 22, 50	7, 57, 20	0, 44, 20	0, 21, 50	0, 22, 30	
21,600	74.16	74.15	74.60	74.60	64.80	66.34	7, 23, 0	7, 33, 30	0, 59, 50	0, 23, 50	0, 36, 0	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.46″
Length of specimen between jaws	77.5″
Dimension of cross section	2 in. dia.
Length of specimen between telescopes	60.00″
Elastic limit in torsion	19,800 in. lbs.
Maximum twisting moment	79,650 in. lbs.
Number of turns of specimen between jaws at fracture	19.1
Outside fiber stress at elastic limit	12,600 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	50,700 lbs. per sq. in.
Angle of twist between 3,600 in. lbs. and 18,000 in. lbs.	2° 44′ 20″
Shearing modulus of elasticity between 3,600 in. lbs. and 18,000 in. lbs.	11,400,000
Average number of turns of specimen per foot at fracture	2.96

TORSION TEST.

Specimen, Swedish Iron. Date, December 2, 1895.

Twisting moment.	Scale Readings. Power end. 1	Power end. 2	Scale end. 1	Scale end. 2	Corrected Mean. Power end.	Scale end.	Angles Corresponding. Power end.	Scale end.	Differences. Power end.	Scale end.	Angle of twist.	Remarks.
							° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	89.57	89.58	86.04	86.04	80.21	77.78	9, 6, 50	8, 50, 30	.....	.....	.....	
7,200	73.42	73.43	75.90	75.90	64.06	67.64	7, 21, 40	7, 42, 20	1, 45, 10	1, 8, 10	0, 37, 0	
10,800	57.80	57.79	66.20	66.20	48.43	57.94	5, 32, 0	6, 36, 40	1, 49, 40	1, 5, 40	0, 44, 0	At 23,400 in. lbs. load the scale beam dropped.
14,400	42.90	42.90	57.20	57.19	33.54	48.93	3, 50, 20	5, 35, 20	1, 41, 40	1, 1, 20	0, 40, 20	
18,000	30.03	30.04	50.30	50.30	20.67	42.04	2, 22, 0	4, 48, 20	1, 28, 20	0, 47, 0	0, 41, 20	
18,000	92.58	92.59	82.93	82.92	83.22	74.66	9, 27, 0	8, 29, 40	.....	.....	.....	Specimen fractured at power end jaw.
19,800	87.00	87.01	80.49	80.48	77.65	72.22	8, 49, 40	8, 13, 10	0, 37, 20	0, 16, 30	0, 20, 50	
21,600	80.56	80.57	77.69	77.70	71.20	69.43	8, 6, 20	7, 54, 20	0, 43, 20	0, 18, 50	0, 24, 30	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90: scale end, 2.80″
Height of center of telescope above center of test piece	5.46″
Length of specimen between jaws	76.75″
Dimension of cross section	2.01 in. dia.
Length of specimen between telescopes	60.00″
Elastic limit in torsion	19,800 in. lbs.
Maximum twisting moment	82,530 in. lbs.
Number of turns of specimen between jaws at fracture	24.3
Outside fiber stress at elastic limit	12,600 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	52,500 lbs. per sq. in.
Angle of twist between 7,200 in. lbs. and 14,400 in. lbs.	1° 24′ 20″
Shearing modulus of elasticity between 7,200 in. lbs. and 14,400 in. lbs.	11,200,000
Average number of turns of specimen per foot at fracture	3.80

TORSION TEST.

Specimen, Swedish Iron. Date, December 5, 1895.

Twisting moment.	Scale Readings. Power end. 1	Power end. 2	Scale end. 1	Scale end. 2	Corrected Mean. Power end.	Scale end.	Angles Corresponding. Power end.	Scale end.	Differences. Power end.	Scale end.	Angle of twist.	Remarks.
							° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
10,800	58.80	58.80	65.47	65.49	49.44	57.22	5, 38, 50	6, 31, 40	.....	.....	.....	
14,400	44.20	44.19	56.72	56.73	34.83	48.46	3, 59, 10	5, 32, 10	1, 39, 40	0, 59, 30	0, 40, 10	
16,200	37.82	37.82	53.11	53.11	28.48	44.85	3, 15, 20	5, 7, 30	0, 43, 50	0, 24, 40	0, 19, 10	At 25,200 in. lbs. load the scale beam dropped.
18,000	31.50	31.52	49 78	49.80	22.15	41.53	2, 32, 10	4, 44, 50	0, 43, 10	0, 22, 40	0, 20, 30	
18,000	91.93	91.92	88.01	88.01	82.56	79.75	9, 22, 40	9, 3, 40	.....	.....	.....	
19,800	86.03	86.01	85.09	85.07	76.66	76.82	8, 43, 0	8, 44, 0	0, 39, 40	0, 19, 40	0, 20, 0	Specimen fractured at power end jaw.
21,600	80.00	80.00	82.03	82.04	70.64	73.77	8, 2, 30	8, 23, 10	0, 40, 30	0, 20, 50	0, 19, 40	
23,400	74.09	74.10	79.22	79.22	64.73	70.96	7, 22, 40	8, 4, 40	0, 39, 50	0, 18, 30	0, 21, 20	
25,200	.....	.....	....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 28.0″
Height of center of telescope above center of test piece	5.46″
Length of specimen between jaws	80.5″
Dimension of cross section	2.00 in. dia.
Length of specimen between telescopes	60.00″
Elastic limit in torsion	23,400 in. lbs.
Maximum twisting moment	84,330 in. lbs.
Number of turns of specimen between jaws at fracture	22.3
Outside fiber stress at elastic limit	14,900 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	53,700 lbs. per sq. in.
Angle of twist between 10,800 in. lbs. and 19,800 in. lbs.	1° 39′ 50″
Shearing modulus of elasticity between 10,800 in. lbs. and 19,800 in. lbs.	11,700,000
Average number of turns of specimen per foot at fracture	3.32

TORSION TEST.

Specimen, Swedish Iron. Date, December 10, 1895.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.	
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
1,800	88.62	88.60	86.06	86.07	79.25	77.80	9, 0, 20	8, 50, 40	.. ..	.. ..	.. ..
3,600	74.60	74.60	75.07	75.07	65.24	66.81	7, 26, 0	7, 36, 40	1, 34, 20	1, 14, 0	0, 20, 20
5,400	62.92	62.92	66.34	66.34	53.56	58.08	6, 6, 50	6, 37, 30	1, 19, 10	0, 59, 10	0, 20, 0
7,200	53.20	53.22	59.59	59.58	43.85	51.32	5, 0, 40	5, 51, 40	1, 6, 10	0, 45, 50	0, 20, 20
9,000	45.27	45.27	54.68	54.68	36.11	46.42	4, 8, 10	5, 18, 10	0, 52, 30	0, 33, 30	0, 19, 0
10,800	38.10	38.10	50.40	50.40	28.74	42.14	3, 17, 20	4, 49, 0	0, 50, 50	0, 29, 10	0, 21, 40
12,600	31.03	31.05	46.26	46.26	21.68	38.00	2, 29, 0	4, 21, 10	0, 48, 20	0, 27, 50	0, 20, 30
12,600	90.13	90.12	90.40	90.40	80.76	82.14	9, 10, 30	9, 19, 50	.. ..	.. ..	.. ..
14,400	85.57	85.57	88.77	88.77	76.21	80.51	8, 40, 0	9, 8, 50	0, 30, 30	0, 11, 0	0, 19, 30
16,200	79.47	79.47	85.66	85.65	70.11	77.40	7, 59, 0	8, 48, 0	0, 41, 0	0, 20, 50	0, 20, 10
18,000	73.20	73.22	82.41	82.40	63.85	74.14	7, 16, 40	8, 26, 0	0, 42, 20	0, 22, 0	0, 20, 20
19,800	67.01	67.01	79.18	79.17	57.65	70.91	6, 34, 40	8, 4, 20	0, 42, 0	0, 21, 40	0, 20, 20
	Piece rested for two hours.										
19,800	72.88	72.88	79.90	79.88	63.52	71.63	7, 14, 20	8, 09, 10	.. ..	.. ..	.. ..
21,600	67.30	67.32	77.26	77.25	57.95	69.00	6, 36, 40	7, 52, 30	0, 38, 40	0, 21, 00	.. ..
23,400	60.98	61.00	74.12	74.10	51.63	65.85	5, 53, 40	7, 30, 10	0, 43, 00	0, 20, 40	.. ..
25,200	Piece would not hold load.										

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.46″
Length of specimen between jaws	75.00″
Dimension of cross section	2.00 in. dia.
Length of specimen between telescopes	60.00″
Elastic limit in torsion	23,400 in. lbs.
Maximum twisting moment	84,960 in. lbs.
Number of turns of specimen between jaws at fracture	18.1
Outside fiber stress at elastic limit	14,900 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	54,100 lbs. per sq. in.
Angle of twist between 1,800 in. lbs. and 7,200 in. lbs.	1° 0′ 40″
Shearing modulus of elasticity between 1,800 in. lbs. and 7,200 in. lbs.	11,700,000
Average number of turns of specimen per foot at fracture	2.90

TORSION TEST.

Specimen, Bessemer Steel. Date, December 16, 1895.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
1,800	92.58	92.58	90.10	90.10	83.58	82.20	9, 29, 20	9, 20, 10	.....	.....	.....	
5,400	60.68	60.67	70.73	70.71	51.68	62.82	5, 54, 0	7, 9, 40	3, 35, 20	2, 10, 30	1, 24, 50	
5,400	88.32	88.30	84.69	84.69	79.31	76.79	9, 0, 50	8, 43, 50	.....	.....	.....	At 19,800 in. lbs. load the scale beam dropped.
9,000	60.97	60.97	69.83	69.83	51.97	61.93	5, 56, 0	7, 3, 40	3, 4, 50	1, 40, 10	1, 24, 40	
9,000	88.01	88.01	84.60	84.59	79.01	76.70	8, 58, 50	8, 43, 20	.....	.....	.....	
12,600	61.20	61.19	70.25	70.27	52.20	62.36	5, 57, 40	7, 6, 30	3, 01, 10	1, 36, 50	1, 24, 20	Specimen fractured at power end jaw.
12,600	89.13	89.15	83.77	83.76	80.14	75.87	9, 13, 0	8, 37, 40	.....	.....	.....	
16,200	63.68	63.70	70.87	70.87	54.69	62.97	6, 14, 50	7, 10, 40	2, 58, 10	1, 27, 0	1, 31, 10	
16,200	88.62	88.64	85.90	85.90	79.63	78.00	9, 3, 0	8, 52, 6	.....	.....	.....	
18,000	76.37	76.39	79.96	79.95	67.38	72.06	7, 40, 30	8, 12, 0	1, 22, 30	0, 40, 0	0, 42, 30	
19,800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale, power end,	3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	58.8″
Dimension of cross section	1.50 in. dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	18,000 in. lbs.
Maximum twisting moment	44,460 in. lbs.
Number of turns of specimen between jaws at fracture	10.5
Outside fiber stress at elastic limit	27,200 lbs. per. sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	67,100 lbs. per. sq. in.
Angle of twist between 1,800 in. lbs. and 9,000 in. lbs.	2° 49′ 30″
Shearing modulus of elasticity between 1,800 in. lbs. and 9,000 in. lbs.	11,700,000
Average number of turns of specimen per foot at fracture	2.14

TORSION TEST.

Specimen, Bessemer Steel. Date, March 5, 1896.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
1,800	92.22	92.23	86.88	86.89	83.22	78.98	9, 27, 0	8, 58, 30	.....	.....	.....	
5,400	54.89	54.89	62.30	62.30	45.89	54.40	5, 14, 40	6, 12, 30	4, 12, 20	2, 46, 0	1, 26, 20	At 18,000 in. lbs. load the
5,400	94.23	94.22	81.39	81.40	85.22	73.49	9, 40, 20	8, 21, 40	.....	.....	.....	scale beam dropped.
9,000	57.10	57.10	57.10	57.10	48.10	49.20	5, 29, 40	5, 37, 10	4, 10, 40	2, 44, 30	1, 26, 10	
9,000	89.95	89.94	78.82	78.82	80.94	70.92	9, 11, 40	8, 4, 20	.....	.....	.....	
12,600	58.10	58.10	59.74	59.72	49.10	51.83	5, 36, 30	5, 55, 10	3, 35, 10	2, 9, 10	1, 26, 0	
12,600	93.80	93.80	84.90	84.89	84.80	76.99	9, 37, 30	8, 45, 10	.....	.....	.....	
16,200	65.59	65.59	69.40	69.39	56.59	61.49	6, 27, 30	7, 0, 40	3, 10, 0	14, 4, 30	1, 25, 30	
16,200	93.60	93.60	88.94	88.94	84.60	80.04	9, 36, 10	9, 8, 10	.....	.....	.....	
18,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	59.1″
Dimension of cross section	1.50 in. dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	16,200 in. lbs.
Maximum twisting moment	45,000 in. lbs.
Number of turns of specimen between jaws at fracture	13.2
Outside fiber stress at elastic limit	24,400 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	67,900 lbs. per sq. in.
Angle of twist between 1,800 in. lbs. and 12,600 in. lbs.	4° 18′ 30″
Shearing modulus of elasticity between 1,800 in. lbs. and 12,600 in. lbs.	11,500,000
Average number of turns of specimen per foot at fracture	2.68

TORSION TEST.

Specimen, Bessemer Steel. Date, March 10, 1896.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
1,800	91.34	91.36	88.88	88.86	82.35	80.97	9, 21, 10	9, 12, 0	.....	.....	.....	
5,400	54.94	54.93	65.01	65.02	45.93	87.11	5, 15, 0	6, 31, 0	4, 6, 10	2, 41, 0	1, 25, 10	At 19,800 in. lbs. load the
5,400	81.42	81.42	81.85	81.85	72.42	73.95	8, 14, 30	8, 24, 50	.....	.....	.....	scale beam dropped.
9,000	51.83	51.85	64.68	64.66	42.84	56.77	4, 53, 50	6, 28, 40	3, 20, 40	1, 56, 10	1, 24, 20	
9,000	85.60	85.62	80.30	80.28	76.61	72.39	8, 42, 40	8, 14, 20	.....	.....	.....	Specimen fractured at
12,600	58.29	58.30	65.54	65.54	49.29	57.64	5, 37, 50	6, 34, 30	3, 4, 50	1, 39, 50	1, 25, 0	power end jaw.
12,600	87.30	87.28	83.21	83.20	78.29	75.30	8, 54, 0	8, 32, 50	.....	.....	.....	
14,400	75.00	75.00	77.20	77.20	66.00	69.30	7, 31, 10	7, 53, 30	1, 22, 50	0, 40, 20	0, 42, 30	
16,200	62.40	62.41	70.98	70.96	53.40	63.07	6, 5, 50	7, 11, 20	1, 25, 20	0, 42, 10	0, 43, 10	
18,000	49.69	49.69	64.50	64.50	40.69	56.60	4, 39, 10	6, 27, 30	1, 26, 40	0, 43, 50	0, 42, 50	
19,800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	58.25″
Dimension of cross section	1.5 in. dia.
Length of specimen between telescopes	40.0″
Elastic limit in torsion	18,000 in. lbs.
Maximum twisting moment	44,920 in. lbs.
Number of turns of specimen between jaws at fracture	10.8
Outside fiber stress at elastic limit	27,200 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	67,800 lbs. per sq. in.
Angle of twist between 1,800 in. lbs. and 12,600 in. lbs.	4° 14′ 40″
Shearing modulus of elasticity between 1,800 in. lbs. and 12,600 in. lbs.	11,700,000
Average number of turns of specimen per foot at fracture	2.22

TORSION TEST.

Specimen, Composition. Date, March, 19, 1896.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
900	91.63	91.63	85.70	85.70	82.63	77.80	9, 23, 0	8, 50, 40	.....	.....	.....	85% copper, 7% spelter, 8% tin.
1,800	84.56	84.57	82.23	82.23	75.56	74.35	8, 35, 40	8, 27, 20	0, 47, 20	0, 23, 20	0, 24, 0	
2,700	78.63	78.64	79.88	79.88	69.64	71.98	7, 55, 40	8, 11, 30	0, 40, 0	0, 15, 50	0, 24, 10	
3,600	70.90	70.92	76.00	76.00	61.91	68.10	7, 3, 40	7, 45, 20	0, 52, 0	0, 26, 10	0, 25, 50	At 6,300 in. lbs. load the scale beam dropped.
4,500	61.20	61.20	71.11	71.12	52.20	63.22	5, 57, 40	7, 12, 20	1, 6, 0	0, 33, 0	0, 33, 0	
5,400	46.20	46.18	65.50	65.50	37.19	57.60	4, 15, 10	6, 34, 20	1, 42, 30	0, 38, 0	1, 4, 30	Fractured 8″ from power end jaw.
6,300	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	28.0″
Dimension of cross section	1.52 in. dia.
Length of specimen between telescopes	20.00″
Elastic limit in torsion	4,500 in. lbs.
Maximum twisting moment	23,130 in. lbs.
Number of turns of specimen between jaws at fracture	3.6
Outside fiber stress at elastic limit	6,530 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	33,500 lbs. per sq. in
Angle of twist between 900 in. lbs. and 2,700 in lbs.	0° 48′ 10″
Shearing modulus of elasticity between 900 in. lbs. and 2,700 in. lbs.	4,810,000
Average number of turns of specimen per foot at fracture	1.54

TORSION TEST.

Specimen, Composition. Date, March 23, 1896.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
720	92.90	92.90	93.00	92.98	83.90	85.09	9, 31, 30	9, 39, 30	.....	.....	.....	85% copper, 7% spelter, 8% tin.
1,440	85.68	85.70	88.55	88.55	76.60	80.65	8, 43, 10	9, 9, 50	0, 48, 20	0, 29, 40	0, 18, 40	
2,160	74.40	74.40	80.05	80.05	65.40	72.15	7, 27, 10	8, 12, 40	1, 16, 0	0, 57, 10	0, 18, 50	
2,880	65.60	65.60	73.95	73.96	56.61	66.06	6, 30, 0	7, 31, 30	0, 57, 10	0, 41, 10	0, 16, 0	At 6,480 in. lbs. load the scale beam dropped.
3,600	56.88	56.90	68.10	68.09	47.89	60.19	5, 28, 20	6, 51, 50	1, 1, 40	0, 39, 40	0, 22, 0	
4,320	49.42	49.43	63.68	63.67	40.42	55.77	4, 37, 20	6, 21, 50	0, 51, 0	0, 30, 0	0, 21, 0	
5,040	41.70	41.70	59.59	59.57	32.70	51.68	3, 44, 30	5, 54, 0	0, 52, 50	0, 27, 50	0, 25, 0	Specimen fractured at power end jaw.
5,760	31.64	31.64	55.00	55.01	22.64	47.10	2, 35, 30	5, 22, 50	1, 9, 0	0, 31, 10	0, 37, 50	
5,760	92.09	92.08	89.94	89.92	.....	.....	.....	.....	.....	.....	.....	
6,480	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of telescope above center of test piece	5.10″
Length of specimen between jaws	27.00″
Dimension of cross section	1.51 in. dia.
Length of specimen between telescopes	20.00″
Elastic limit in torsion	5,040 in. lbs.
Maximum twisting moment	28,800 in. lbs.
Number of turns of specimen between jaws at fracture	5.0
Outside fiber stress at elastic limit	7,460 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	42,600 lbs. per sq. in.
Angle of twist between 720 in. lbs. and 2,160 in. lbs.	0° 37′ 30″
Shearing modulus of elasticity between 720 in. lbs and 2,160 in. lbs.	5,210,000
Average number of turns of specimen per foot at fracture	2.22

TORSION TEST.

Specimen, Brass. Date, March 25, 1896.

Twisting moment.	Scale Readings. Power end. 1	Power end. 2	Scale end. 1	Scale end. 2	Corrected Mean. Power end.	Corrected Mean. Scale end.	Angles Corresponding. Power end. ° ′ ″	Angles Corresponding. Scale end. ° ′ ″	Differences. Power end. ° ′ ″	Differences. Scale end. ° ′ ″	Angle of twist. ° ′ ″	Remarks.
720	91.03	91.03	88.33	88.31	82.03	80.42	9, 19, 0	9, 8, 10	.....	.....	.. .. ..	
1,440	77.89	77.91	78.12	78.11	68.90	70.22	7, 50, 40	8, 0, 20	1, 28, 20	1, 7, 50	0, 20, 30	65% copper,
2,160	64.35	64.33	67.62	67.62	55.34	59.70	6, 19, 0	6, 48, 30	1, 31, 40	1, 11, 50	0, 19, 50	35% spelter.
2,520	57.20	57.20	62.26	62.28	48.20	54.37	5, 30, 20	6, 12, 20	0, 48, 40	0, 36, 10	0, 12, 30	
2,880	50.46	50.48	57.70	57.70	41.47	49.80	4, 44, 30	5, 41, 20	0, 45, 50	0, 31, 0	0, 14, 50	Specimen fractured at
3,240	42.65	42.66	52.55	52.57	33.66	44.66	3, 51, 0	5, 6, 10	0, 53, 30	0, 35, 10	0, 18, 20	center.
3,600	32.81	32.80	46.40	46.39	23.81	38.50	2, 43, 35	4, 24, 10	1, 7, 25	0, 42, 0	0, 25, 25	
3,960	91.52	91.51	88.71	88.70	82.52	78.80	9, 22, 25	9, 10, 50	.....	.....	.....	
4,320	69.15	69.13	81.10	81.16	60.14	73.20	6, 31, 30	8, 19, 20	2, 50, 55	0, 49, 30	2, 1, 25	
4,680	26.73	26.75	68.75	68.77	17.74	61.80	2, 2, 0	7, 2, 40	4, 29, 30	1, 16, 40	3, 12, 50	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	28.00″
Dimension of cross section	1.51 in. dia.
Length of specimen between telescopes	20.00″
Elastic limit in torsion	3,600 in. lbs.
Maximum twisting moment	17,460 in. lbs.
Number of turns of specimen between jaws at fracture	3.5
Outside fiber stress at elastic limit	5,220 lbs. per sq in.
Apparent outside fiber stress as calculated from maximum twisting moment	25,900 lbs. per sq. in.
Angle of twist between 720 in. lbs. and 2,520 in. lbs.	0° 52′ 50″
Shearing modulus of elasticity between 720 in. lbs. and 2,520 in. lbs.	4,380,000
Average number of turns of specimen per foot at fracture	1.50

TORSION TEST.

Specimen, Bessemer Steel. Date, March 26, 1896.

Twisting moment.	Scale Readings. Power end. 1	Power end. 2	Scale end. 1	Scale end. 2	Corrected Mean. Power end.	Corrected Mean. Scale end.	Angles Corresponding. Power end. ° ′ ″	Angles Corresponding. Scale end. ° ′ ″	Differences. Power end. ° ′ ″	Differences. Scale end. ° ′ ″	Angle of twist. ° ′ ″	Remarks.
1,800	91.85	91.85	78.45	78.44	82.85	70.54	9, 24, 20	8, 1, 50	.. .. ..	.....	.. .. ..	
3,600	73.10	73.10	65.90	65.91	64.10	65.90	7, 18, 20	6, 39, 40	2, 6, 0	1, 22, 10	0, 43, 50	At 19,800 in. lbs. load the
5,400	57.34	57.36	56.62	56.62	48.35	48.72	5, 31, 20	5, 34, 0	1, 47, 0	1, 5, 40	0, 41, 20	scale beam dropped.
7,200	42.76	42.77	48.22	48 22	33.76	40.32	3, 51, 45	4, 36, 40	1, 39, 35	0, 57, 20	0, 42, 15	
9,000	27.98	27.99	39.60	39.60	18.98	31.70	2, 10, 30	3, 37, 40	1, 41, 15	0, 59, 0	0, 40, 15	Specimen fractured at
9,000	93.78	93.80	90.00	89.98	84.79	82.09	9, 37, 30	9, 19, 30	.....	.....	.. .. ..	power end jaw.
10,800	77.55	77.56	81.80	81.80	68.55	73.90	7, 48, 30	8, 24, 25	1, 49, 0	0, 55, 5	0, 53, 55	
10,800	94.10	94.08	87.30	87.30	85.09	79.40	9, 39, 30	9, 1, 40	.....	.....	.....	
12,600	80.36	80.36	79.80	79.79	71.36	71.69	8, 7, 20	8, 12, 30	1, 32, 10	0, 49, 10	0, 43, 0	
14,400	66.90	66.92	72.60	72.60	57.91	64.70	6, 36, 20	7, 22, 20	1, 31, 0	0, 50, 10	0, 40, 50	
16,200	53.78	53.78	65.72	65.70	44.78	57.81	5, 7, 0	6, 35, 40	1, 29, 20	0, 46, 40	0, 42, 40	
18,000	41.58	41.60	59.67	59.66	32.59	51.76	3, 43, 40	5, 54, 40	1, 23, 20	0, 41, 0	0, 42, 20	
19,800	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.10″
Length of specimen between jaws	58.0″
Dimension of cross section	1.50 in. dia.
Length of specimen between telescopes	40.00″
Elastic limit in torsion	18,000 in. lbs.
Maximum twisting moment	45,540 in. lbs.
Number of turns of specimen between jaws at fracture	11.4
Outside fiber stress at elastic limit	27,200 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	68,700 lbs. per sq. in.
Angle of twist between 1,800 in. lbs. and 9,000 in. lbs.	2° 49′ 40″
Shearing modulus of elasticity between 1,800 in. lbs. and 9,000 in. lbs.	11,700,000
Average number of turns of specimen per foot at fracture	2.36

TORSION TEST.

Specimen, Swedish Iron Bar. Date, March 27, 1896.

Twisting moment.	Scale Readings.				Corrected Mean.		Angles Corresponding.		Differences.		Angle of twist.	Remarks.
	Power end.		Scale end.		Power end.	Scale end.	Power end.	Scale end.	Power end.	Scale end.		
	1	2	1	2			° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
3,600	93.46	93.46	91.11	91.11	84.10	82.85	9, 32, 50	9, 24, 30	.....	.....	.....	
7,200	72.10	72.10	75.69	75.69	62.74	67.43	7, 9, 10	7, 40, 50	2, 23, 4	1, 43, 40	0, 40, 0	At 25,200 in. lbs. load the scale beam dropped.
10,800	54.10	54.10	63.60	63.60	44.74	55.34	5, 6, 50	6, 19, 0	2, 2, 20	1, 21, 50	0, 40, 30	
14,400	40.40	40.40	55.69	55.68	31.04	47.42	3, 33, 10	5, 25, 0	1, 33, 40	0, 54, 0	0, 39, 40	
18,000	28.11	28.11	49.14	49.17	18.75	40.88	2, 8, 50	4, 40, 30	1, 24, 20	0, 44, 30	0, 39, 50	Specimen fractured at power end jaw.
18,000	94.00	94.00	88.84	88.85	84.64	80.59	9, 36, 30	9, 9, 20	.....	.....	.....	
19,800	97.60	87.60	85.45	85.45	78.24	77.19	8, 53, 40	8, 46, 30	0, 42, 50	0, 22, 50	0, 20, 0	
21,600	81.60	81.60	82.45	82.45	72.24	74.19	8, 13, 20	8, 26, 20	0, 40, 20	0, 20, 10	0, 20, 10	
23,400	75.88	75.88	79.78	79.78	56.52	71.52	7, 34, 20	8, 8, 30	0, 39, 0	0, 17, 50	0, 21, 50	
25,200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

Distance from center of test piece to scale	500.0″
Reading of level of center of test piece on scale	power end, 3.90; scale end, 2.80″
Height of center of telescope above center of test piece	5.46″
Length of specimen between jaws	79.00″
Dimension of cross section	2.02 in. dia.
Length of specimen between telescopes	60.00″
Elastic limit in torsion	23,400 in. lbs.
Maximum twisting moment	82,350 in. lbs.
Number of turns of specimen between jaws at fracture	21.0
Outside fiber stress at elastic limit	14,300 lbs. per sq. in.
Apparent outside fiber stress as calculated from maximum twisting moment	50,400 lbs. per sq. in.
Angle of twist between 36,000 in. lbs. and 18,000 in. lbs.	2° 40′ 0″
Shearing modulus of elasticity between 36,000 in. lbs. and 18,000 in. lbs.	11,300,000
Average number of turns of specimen per foot at fracture	3.19

Rope Tests.

ROPE TESTS.

Date.	Specimen.	Size. Circumference. (Inches.)	Number of strands.	Feet per pound.	Turns per foot.	Method of holding.
1895.						
Oct. 21	Manila.	3	3	2.26	4.2	Eye splices.
Oct. 21	Manila.	4	3	1.57	3 0	Eye splices.
Oct. 23	Manila.	3	3	2 83	5.3	Eye splices and bowline.
Oct. 25	Manila.	3	3	2.38	4.0	Eye splices.
Oct. 28	Manila.	3	3	2.50	4.0	Eye splices. (Not tapered.)
Oct. 28	Manila.	4	3	2.90	4.0	Eye splices. (Not tapered.)
Oct. 30	American hemp. (Dry.)	3½	3	1.90	7.0	Eye splices.
Nov. 1	American hemp. (Dry.)	3	3	....	5.0	Eye splices.
Nov. 4	Russian hemp. (Dry.)	2½	3	....	5 7	Eye splices.
Nov. 6	Russian hemp. (Tarred.)	2½	3	3.67	5.5	Eye splices.
Nov. 6	Sisal.	3	3	2.90	4.5	Eye splices.
Nov. 8	American hemp. (Dry.)	2½	3	6.30	6.0	Eye splices.
Nov. 11	Cotton.	2	3	11.62	9.0	Eye splices.
Nov. 13	Cotton.	2	3	11.43	9.0	Eye splices.
Nov. 14	Manila.	7	3	1.00	2.0	Eye splices.
Nov. 15	Manila.	7	3	.75	2.0	Eye splices.
Nov. 18	Cotton.	2	3	10.00	9.0	Eye splices.
Nov. 19	American hemp. (Dry.)	2½	3	18.00	6.0	Eye splices.
Nov. 20	Russian hemp. (Dry.)	3	3	....	5.5	Eye splices.
Nov. 20	Russian hemp. (Tarred.)	3	3	....	6.0	Eye splices.
Nov. 22	Russian hemp. (Dry.)	2½	3	5.00	5.7	Eye splices.
Nov. 22	Russian hemp. (Tarred.)	2½	3	4.30	6.0	Eye splices.
Nov. 25	American hemp. (Dry.)	2½	3	5.75	5.3	Eye splices.
Nov. 25	American hemp. (Tarred.)	2½	3	4.38	5.0	Eye splices.
Nov. 27	Sisal.	3	3	3 60	4.5	Eye splices.
Dec. 2	Sisal.	3	3	3.64	5 0	Eye splices.
Dec. 2	Sisal.	3	3	3.70	5.0	Eye splices.
Dec. 4	Cotton.	2	3	11.40	8 7	Eye splices.
Dec. 6	American hemp. (Dry.)	2½	3	5.83	18.0	Eye splices.
Dec. 6	American hemp. (Tarred.)	2½	3	5.00	5.0	Eye splices.
Dec. 9	American hemp. (Dry.)	3	3	3.92	15.0	Eye splices.
1896.						
Mar. 4	American hemp. (Dry.)	2½	3	5.77	6.0	Eye splices.
Mar. 5	Cotton.	2	3	11.50	9.0	Eye splices.
Mar. 5	Manila.	2½	3	5.33	5.3	Eye splices.
Mar. 6	Cotton.	2	3	11.56	9.0	Eye splices.
Mar. 10	Russian hemp. (Tarred.)	2½	3	....	5.5	Eye splices.
Mar. 10	Manila.	2½	3	5.20	5.5	Eye splices.
Mar. 10	American hemp. (Dry.)	2½	3	3.68	5.0	Eye splices.
Mar. 11	Sisal.	3	3	3.70	5.0	Eye splices.
Mar. 23	Manila.	3	3	3.91	4.0	Eye splices.
Mar. 25	Manila.	3	3	5.00	4.0	Eye splices.
Mar. 26	Manila.	3	3	4.00	4.2	Eye splices.
Mar. 30	Manila.	3	3	4.70	4.3	Eye splices.
Mar. 30	Manila.	3	3	4.70	4.3	Eye splices.
Mar. 31	Manila.	3	3	5.00	4.0	Eye splices.
April 1	Manila.	3	3	5.00	4.1	Eye splices.

ROPE TESTS. — *Continued.*

Condition.	Location of break.	Breaking load. (Lbs.)	Remarks.
Dry. Wet splices.	Center.	8,906	
Dry.	Splice.	10,136	
Dry. Wet splices.	Bowline.	3,480	
Dry. Wet splices.	Center.	9,574	
Dry. Wet splices.	Center.	5,829	One strand slightly damaged before test.
Dry. Wet splices.	Splice.	8,031	
Dry. Wet splices.	Lower splice.	7,220	
Dry. Wet splices.	Lower splice.	7,354	
Dry. Wet splices.	Center.	7,021	
Dry. Wet splices.	Center.	5,252	
Dry. Wet splices.	Lower splice.	6,214	
Dry. Wet splices.	Center.	5,980	
Dry. Wet splices.	Center.	1,789	
Dry. Wet splices.	Center.	1,986	
Dry.	Upper splice.	22,394	
Dry. Wet splices.	Center.	24,551	
Dry. Wet splices.	Center.	1,870	
Dry. Wet splices.	Splice.	4,749	
Dry. Wet splices.	Splice.	7,206	
Dry. Wet splices.	Lower splice.	5,074	
Dry. Wet splices.	Upper splice.	6,876	
Dry. Wet splices.	Center.	4,697	
Dry. Wet splices.	Upper splice.	4,098	
Dry. Wet splices.	Upper splice.	4,231	
Dry. Wet splices.	Upper splice.	5,637	
Dry.	Lower splice.	4,400	
Dry.	Lower splice.	6,465	
Dry. Wet splices.	Center.	1,508	
Dry. Wet splices.	Upper splice.	4,648	
Dry. Wet splices.	Upper splice.	5,620	
Dry. Wet splices.	Lower splice.	6,831	
Dry. Wet splices.	Lower splice.	3,922	
Dry. Wet splices.	No break.	.....	Maximum load = 1,831 lbs. Specimen stretched beyond limit of machine.
Dry.	Splice.	4,712	
Dry. Wet splices.	Center.	1,776	
Dry. Wet splices.	Center.	5,786	
Dry. Wet splices.	Center.	5,295	
Dry. Wet splices.	Upper splice.	7,267	Uninjured ends of two broken specimens joined by square knot.
Dry.	Knot.	3,560	
Dry. Wet splices.	Knot.	4,439	Left handed overhand knot at center.
Dry. Wet splices.	Knot.	4,739	Right handed overhand knot at center.
Dry. Wet splices.	Knot.	4,044	Figure eight knot at center.
Dry. Wet splices.	Knot.	6,320	Ordinary overhand tie at center.
Dry. Wet splices.	Knot.	3,780	Open hand knot at center.
Dry. Wet splices.	Knot.	5,386	Shroud knot at center.
Dry. Wet splices.	Knot.	5,169	Weaver's knot at center.

INVESTIGATION TO DETERMINE WHETHER DIPHENYLIODONIUM AND THALLIUM NITRATES ARE ISOMORPHOUS.

By A. A. NOYES, Ph.D., and C. W. HAPGOOD, S.B.

Received June 15, 1896.

The great similarity in properties observed by V. Meyer[1] between the salts of thallium and diphenyliodonium, $(C_6H_5)_2$I-OH, made it seem not improbable that they might be also isomorphous with each other. The matter seemed worthy of investigation, as only a few such cases of isomorphous replacement of single atoms by complex organic radicals are known.

According to the extended investigations of Retgers, by far the most reliable criterion of isomorphism is furnished by the power of the substances in question of forming homogeneous mixed crystals with the proportions varying continuously within wide limits. Consequently, the experimental method based on this principle as described by Retgers[2] was followed, chemical analysis and specific gravity determinations being employed to determine the character of the crystals separating from the solution. Preliminary experiments showed that the largest and most perfect crystals were obtained with the nitrates when crystallized from alkaline solution. Saturated solutions of thallous nitrate in water and of diphenyliodonium nitrate[3] in a moderately strong aqueous solution of the free base, diphenyliodonium hydrate, were therefore prepared, mixed with each other in crystallizing dishes in varying proportions, and allowed to stand in a vacuum desiccator till a sufficient quantity of crystals had separated. The solutions were mixed in the following proportions, the number of parts of the diphenyliodonium nitrate solution being given

[1] Berichte der deutschen chemischen Gesellschaft, 27, 502, 1592.

[2] Zeitschrift für physikalische Chemie, 4, 593.

[3] Made as described by Hartmann and V. Meyer, Berichte der deutschen chemischen Gesellschaft, 27, 506.

first: 10:1.1; 10:2; 10:5; 10:6.7; 10:10; 10:15; 10:20; 10:50; and 10:90.

The first crop from the last solutions consisted of two distinct kinds of crystals, one kind much lighter and the other much heavier than methylene iodide. In all the other cases only one kind of crystals, which were lighter than methylene iodide, was obtained. The specific gravity of these lighter crystals separating from each of the nine solutions was determined by the suspension method of Retgers,[1] the value taken being that corresponding to the heaviest crystals of each lot. The results varied irregularly between 1.866 and 1.889. For the pure diphenyliodonium nitrate we found 1.868. For thallous nitrate Lamy[2] found 5.8. The lighter crystals were therefore in all nine cases practically pure diphenyliodonium nitrate. The heavier crystals from the last solutions were mixed together, dried at 100°, and analyzed by heating in a crucible with concentrated sulphuric acid and igniting. Two separate determinations showed them to contain 99.83 and 99.93 per cent. of thallous nitrate.

Thus the two salts crystallize out separately from the solution in the pure state, not in the form of mixed crystals. They are therefore not isomorphous.

[1] Zeitschrift für physikalische Chemie, 3, 289.

[2] Annales de chimie et de physique (3), 67, 409.

THE PRESENCE OF NITRITES IN THE AIR.

By GEORGE DEFREN, M.S.

Received May 9, 1896.

It is well known that the atmospheric air contains besides its main normal constituents, oxygen and nitrogen, admixtures in varying quantities of not only carbon dioxide and aqueous vapor, but, especially in the neighborhood of cities,[1] ammonia and various gases arising from industrial processes and resulting from the decomposition of animal and vegetable life.

The amounts of the impurities in the air may be very small. Ammonia exists sometimes to the extent of one part in 1,000,000. Ozone is said to be produced by electrical discharges during storms, by the breaking of waves on rocks, and other causes.[2] It has been shown[3] that when ammonia and ozone unite in the air they form hydrogen peroxide, ammonium nitrite, and ammonium nitrate. It has also been observed[4] that rain obtained during thunder storms contained more nitrites and nitrates than ordinary rain, from which we conclude that electrical discharges have some effect on this combination.

Aside from the above several investigations have been carried out to determine the origin of nitrites in the air and the possible effect of these nitrites on the human system. Böke[5] claims that when illuminating gas is burned the higher oxides of nitrogen are formed. W. V. Hoffmann[6] noticed that on combustion a gas was formed which had a reddish color and possessed an odor resembling

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[1] Mabery and Snyder: Jour. Am. Chem. Soc., 17, 105.

[2] Gorup V. Besanez: Ann. Chem. Pharm., 161, 232.

[3] Carius: Ber. deut. chem. Gesel., 8, 1481.

[4] Goppelsröder: Jour. f. pract. Chem. [2], 4, 139, 383; Smith: "On Air and Rain," 438; Bechi: Ber. deut. chem. Gesel., 8, 1203.

[5] Chem. News, 22, 57.

[6] Ber. deut. chem. Gesel., 1870, 658.

that of nitrous acid. E. A. Greete and P. Zoeller showed[1] by a conclusive investigation that when absolutely pure hydrogen was burned in pure air the condensed water formed showed an appreciable quantity of nitrous acid by the use of Griess' reagent. Berthelot[2] and Stohmann[3] found that by the combustion of nitrogenous bodies nitrous, nitric, and hyponitrous acids were formed. Leeds,[4] Wurster,[5] and Wright[6] also found nitrous acid as a product of the combustion of illuminating gas. Louis Ilosvay de N. Ilosva[7] made extensive researches on the subject, and came to the conclusion that the higher oxides of nitrogen were formed, but that no ozone nor hydrogen peroxide could be obtained. The presence of hydrogen peroxide in snow and rain[8] was due to other causes. Finally Alfred Von Bibra[9] investigated the question, and obtained considerable nitrous acid when illuminating gas was burned. Mabery and Snyder[10] have recently determined the amounts of nitrites found in air in various localities.

That headache and depression are experienced in crowded rooms is universally recognized, but the exact cause is not yet clearly determined. Formerly the presence of excessive carbon dioxide was supposed to be sufficient to account for the evil effects of bad air, but the researches of Hammond, Brown-Sequard and D'Arsonval,[11] and Merkel[12] claim the presence of a volatile organic poison in the fluid condensed from expired air. The results have, however, been contested by Dostre and Loye,[13] Russo Gilibert and Alessi,[14] Hofmann-Wellenhof,[15] Lehmann and Jessen,[16] Bergey, Mitchell, and Bil-

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[1] Ber. deut. chem. Gesel., 1877, 2144*b*.
[2] Comptes Rendus, 89, 882.
[3] Jour. f. pract. Chem., 19, 142.
[4] Am. Chem. Soc. J., 1884, 3; Chem. News, 49, 237.
[5] Ber. deut. chem. Gesel., 1886, 3202, 3206.
[6] Chem. Soc. J., 37, 422; Chem. News, 41, 169; Chem. Ind., 1880, 207.
[7] Bull. soc. chem. d. Par., 1889, 2, 377; Ber. deut. chem. Gesel., 1889, 793.
[8] Schöne: Ber. deut. chem. Gesel., 7, 1695.
[9] Archiv f. Hygiene, 15, 216.
[10] Jour. Am. Chem. Soc., 17, 121.
[11] Comptes Rendus, 1888, 33; Société de Biol., 90, 99, 108, 110.
[12] Archiv f. Hygiene, 15, 1.
[13] Comptes Rendus, 88, 91–99.
[14] Bolletino della Società d'igiene di Palermo, 88, Nr. 9.
[15] Wiener Klinische Wochenschrift, 88, Nr. 37.
[16] Archiv f. Hygiene, 10, 267.

lings.[1] The latter named investigators claim that the injurious effects of air expired from the lungs appear to be due entirely to the diminution of oxygen or increase in carbon dioxide, or to a combination of these two factors, and state that it is improbable that the minute quantity of organic matter contained in expired air has any deleterious influence on men who inhale it in crowded rooms.

Even if no organic poison be exhaled from the lungs it is nevertheless a fact[2] that mice placed in closed receptacles and forced to breathe the expired air from other mice quickly died, showing the presence of some harmful substance. In direct connection with this observation stand the results obtained by Falck,[3] Husemann,[4] Charier,[5] Sucquet,[6] Desgranges,[7] Eulenberg,[8] Purcell,[9] Schmitz,[10] and Pott[11] on the poisonous qualities of nitrous acid.

With the more delicate methods of determining nitrites it has been proved that they exist in the air of inhabited rooms; hence the question naturally arises, Could the presence of *nitrites* in the air exert any influence in causing the effects hitherto wholly attributed to the carbonic acid gas? Ilosvay[12] claims that nitrites are exhaled from the lungs, and Wurster[13] and Cramer[14] maintain that the nitrites formed by the combustion of illuminating gas are the direct cause of the depressed feeling and uneasiness experienced in crowded rooms, while Rübner shows[15] that the humidity and rise of temperature possess an appreciable influence on the animal organism.

Comparatively little attention has been paid to the quantity of nitrites present in the air of inhabited rooms, and directions for these compounds are not available for the general student. The

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[1] Report to Smithsonian Institution; Nat. Acad. Science, April 16, 1895; Science, New Series, 1, 481, 482.

[2] Merkel: Loc. cit.

[3] Lehrbuch d. prakt. Toxicologie, 1880, S. 64.

[4] Lehrbuch d. Toxicologie.

[5] Bull. de la soc. med. d'emulat, 1823.

[6] Jour. d. méd., 1860.

[7] Jour. d. méd., T. 8.

[8] Die Lehre von d. gift. Gasen, 1865, S. 251.

[9] Med. a. Surg. Report, 1872, p. 313.

[10] Berl. kl. W. Schr., 1883, S. 428; 1884, S. 335.

[11] D. med. Woch., 1884, 29–30.

[12] Loc. cit. Ber., 798 c.; Bull. Soc. Chem., 388–391.

[13] Ber. deut. chem. Gesel., 1886, 3202, 3206.

[14] Jour. f. Gasbeleucht. u. Wasserversorg, 1891, 65; Archiv f. Hygiene, 10, 321.

[15] Archiv f. Hygiene, 16, 101.

object of the work here reported was to show that nitrites do exist in the air in appreciable though small quantity, that the amount of nitrites is varying under varying conditions, and that they increase in the same manner and under like circumstances as does carbon dioxide, thus indicating that they are products of combustion.

That nitrites do exist in the air of rooms is evident from the fact that 100 cc. of pure water treated with a mixture of 1 cc. hydrochloric acid (1 : 4), 2 cc. sulphanilic acid, and 2 cc. naphthylamine hydrochlorate solution, and exposed to the air, rapidly takes on a deep pink color, due to the absorption of nitrites from the air by the water, forming *a*-naphthylamine-azo-benzenesulphonic acid. For this reason the various "standards" used in estimating the amounts of nitrites in water are always freshly prepared on making an analysis to prevent as much as possible any liability of error in the determination.

The work described below was carried on in the Walker Building of the Massachusetts Institute of Technology. This structure has the reputation of being one of the best ventilated in the country, the air in the laboratories being completely changed once in seven minutes, so that some of the results obtained will be somewhat different from those possible in places where not so much attention is given to obtaining a good supply of fresh air.

The first experiment tried was to determine the rate of absorption of nitrites by water in various laboratories. 100 cc. of redistilled water were placed in each of three porcelain evaporating dishes (15 cm. in diameter), which gave in each case a superficial area of water exposed to the air of about 95 sq. cm. These were then allowed to stand for specified times in a room, and the amounts of nitrites absorbed by the water determined in the usual manner. The redistilled water used was that employed by the Massachusetts State Board of Health in making its various standards for determining the amounts of ammonia, nitrites, and nitrates, thus insuring the freedom of the water from these substances.

The absorption of nitrites by water in Room 36, Walker Building, was first determined. During the day on which this experiment was carried on no water analyses were in progress. One gas burner had been in use a part of the morning. In the latter part of the afternoon two lamps were burning till after five o'clock. An apparatus for furnishing hot water, heated by means of gas, was put into

service at 3.30 P.M. and left burning till after five o'clock. In this room there were also, on an average, three persons employed during the day.

The three porcelain dishes containing each 100 cc. of best redistilled water free from nitrites were placed side by side on a desk and exposed to the air for varying lengths of time, being then treated with the reagents named above — the depth of color produced by this means being compared to that of standard potassium nitrite solutions (1 cc. containing .0000001 gram nitrogen as nitrite) treated with the same reagents.

An analogous experiment was tried in Room 38 of the same building. During the morning one lamp had been burning one hour. Work was carried on by three persons during various portions of the day — they, however, not requiring the use of any gas burners. The three porcelain dishes were placed in position on a desk at two o'clock in the same manner as in the preceding case.

The third trial of the series was made with the air in Room 39. Four Bunsen burners had been in use all day, being turned out at five o'clock. Three students had been at work the greater part of the time, and at occasional intervals others were also present. The first two samples of water were placed in position at 2 P.M., and the third, which was exposed for seventeen hours, was placed in position at 4 P.M. The results of these series of experiments are given in the following table:

Room.	Hours of Exposure.			
	1.	2.	17.	19.
	cc. equivalent nitrite solution.			
36	2.5	3.5	—	57.2
38	3.5	8.5	—	72.7
39	8.0	13.5	84.2	—

On examining the above results we notice the following:

1. Even in the air of the best ventilated rooms where gas is burned nitrites exist.

2. Water exposed undisturbed to the air absorbs nitrites there existing.

3. The amount of nitrites so absorbed increases in almost direct proportion to the time the water is exposed, being also dependent, however, on the nature of the work carried on in the room.

4. On burning illuminating gas some of the nitrogenous constituents, though small in amount, are incompletely oxidized to nitrites.

The investigation next carried out was to make a quantitative estimation of the nitrites by volume by a method similar to that usually made use of in determining the quantity of carbon dioxide in the air of buildings. Two large bottles, the capacities of which were known, were placed side by side, and the air to be analyzed was drawn into them, using suction, one tube reaching nearly to the bottom of the bottle. They were then tightly closed with rubber stoppers and taken to the room where they were to be tested. 100 cc. best redistilled water free from nitrites were then introduced, the bottles allowed to stand, with occasional shaking, for more than twelve hours — in some cases for as many as twenty-four hours — before analysis. The water was then tested for nitrites in the usual manner.

Two samples of air from Room 36 were taken at 3.30 P.M. Fifteen lamps had been in use for about two hours. Three persons were employed during the day in this laboratory.

Two samples of air were also taken from Room 38 at nine o'clock in the morning. During the night preceding the room had been unoccupied, and no lamps had been in use up to the time of taking the samples. The bottles with 100 cc. water were allowed to stand until next morning and then analyzed for nitrites.

Two samples of air from Room 39 were taken at the same time as the preceding under the same conditions.

During the afternoon (at 3.30) two other samples of air were taken from this room in order to see whether any variation had taken place in the amounts of nitrites present. The samples were collected as in the previous cases. Eight Bunsen burners had been in use since 9 A.M., and were still burning at the time the air was taken for analysis. Three persons were employed in this laboratory during the day.

The amounts of nitrites absorbed by the water were determined in the usual manner. To see whether all the nitrites had been absorbed from the air in these bottles a little nitrite-free water was introduced after the above test. This water gave only a very faint coloration when treated with Griess' reagent, proving that nearly all the nitrite had been removed.

The temperature of the air was 20° C. at the time the analyses were made, and the barometric pressure was 758 mm.

The results obtained are as follows, the nitrogen equivalent being calculated as nitrous anhydride:

Room.	Time of taking sample.	Capacity bottle. cc.	cc. of nitrite equivalent.	Parts N_2O_3 in 10,000 air.
38	9 A.M.	8,980	8.5	.0140
38	9 A.M.	8,870	8.3	.0138
36	3.30 P.M.	8,980	19.5	.0319
36	3.30 P.M.	8,870	18.9	.0315
39	9 A.M.	8,870	24.6	.0408
39	9 A.M.	8,320	25.7	.0456
39	3.30 P.M.	8,870	43.2	.0690
39	3.30 P.M.	8,320	40.0	.0707

On inspecting the above results we see that (1) in the air of rooms the amount of nitrites is, as a rule, very small, on a clear day as little as .014 part in 10,000 parts air having been found; (2) the burning of illuminating gas and the presence of people seem to cause an increase in the quantity of nitrites present in the air.

Reference has been made as to the possibility of persons being a factor in causing the increase in quantity of nitrites in the air. That nitrites are formed through human metabolism is evidenced by the fact that the water in which the hands are washed give, on the addition of Griess' reagent, a very strong test for nitrites.

Trial was made to ascertain whether during the breathing process of man nitrites are exhaled. To this end 100 cc. of redistilled water were placed in a large test tube and exhaled air blown through this water from the lungs for five minutes. The water was then treated for nitrites in the usual manner. No pink-colored solution was formed, thus showing that expired air on passing through pure water does not give an indication of nitrites. This circumstance does not, however, prove conclusively that nitrites are absent in air which has passed through the lungs. There is a great probability that air containing a small amount of nitrite in the presence of a comparatively great quantity of oxygen on passing through water oxidizes these nitrites

to nitrates, or even decomposes them to nitrogen. That this is evidently so is seen from the fact that a stream of air drawn through pure water by means of suction also failed to give any indication of nitrites, though water left exposed, undisturbed in this same air, gave a very decided test.

It has also been mentioned that rain water obtained during a thunder shower contained more nitrogen as nitrite and nitrate[1] than rain tested when there were no electrical discharges in the atmosphere. It seemed, therefore, probable that the larger part of the nitrites and nitrates were washed from the air during a rain storm. This was proved to be the case, for two porcelain dishes, containing each 100 cc. of water, absorbed nitrites equivalent to 10 and 11 "standards," respectively, just before a rain storm. Immediately after the rain ceased one dish, exposed for one hour, gave an indication of 0.2 "standard," while another gave 0.4 "standard," showing that the air is very thoroughly washed during a heavy fall of rain.

It will be seen from the above that the results which I have obtained, though not numerous, deal yet with a subject hitherto little considered. Some of the determinations do not directly confirm what I had expected. Further experiment may lead to definite results, and although it is my intention to continue the investigation, I also hope that this fragmentary presentation may stimulate others to further work on the subject.

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[1] Loc. cit. (See above.)

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TECHNOLOGY QUARTERLY

AND PROCEEDINGS OF THE

SOCIETY OF ARTS

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Reprinted from *Technique* '97, 1896.

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. IX. DECEMBER, 1896. No. 4.

HENRY SALTONSTALL.[1]

IN his annual report, December 9, 1891, the President of the Institute of Technology made the following remark: "I long ago said that the greatest crisis through which a young institution of learning is called to pass, is, not with respect to its general scheme of work, not with respect to its finances, not with respect to its Faculty, but with respect to its Board of Trustees." What he then said on the subject of the cardinal importance of a right choice of trustees in an institution of learning, especially in its early days, he would now repeat with even more of emphasis, not only as the result of four years of added experience, but also out of his deep sense of the painful loss which the Institute of Technology has recently suffered in the death of one of its wisest, strongest, and bravest counselors.

Henry Saltonstall was born into one of the most distinguished families of Massachusetts, at Salem, the second of March, 1828. He fitted for college at Salem and at the Phillips Exeter Academy, entering Harvard in 1843; but by reason of ill health was obliged to give up his studies and go to sea. Returning after a year's absence, he reëntered college, becoming a member of the Class of 1848, in which he graduated seventh in scholarly rank, a Φ. B. K., and second marshal on class day.

[1] Reprinted from *Technique* '97, 1896.

It is not needful to dwell at length upon Mr. Saltonstall's business career. It was from first to last marked by a masterly comprehension of affairs, by calm courage and decisive energy. He was for some years engaged in the East India trade, but when the outbreak of our Civil War made this line of business both unremunerative and hazardous he took up the work of textile manufacturing, to which he was to devote the remainder of his life. His first charge was the treasurership of the Chicopee Manufacturing Company, a small mill, which he ran to its fullest capacity throughout the war, often by night as well as by day, with a double staff of operatives. When he left this mill, in 1880, it had doubled its machinery, and its shares had advanced to five times their price in 1862. Meanwhile, in 1876, Mr. Saltonstall accepted the additional charge of the well-known Atlantic Mill at Lawrence, then lying idle and in a condition rapidly going from bad to worse. Within six months after Mr. Saltonstall became treasurer the mill was running with a full force, and in spite of unfavorable business conditions a substantial profit had been made. Mr. Saltonstall's success as manager of the two mills which have been named brought to him in 1880 an offer of the treasurership of the Pacific Mills in Lawrence, the largest and most important mills in this country, if not in the world. The story of Mr. Saltonstall's triumphant success in this great undertaking is common fame throughout Massachusetts and the whole textile manufacturing region of the United States. The condition of the mill was such as to require enormous expenditures — expenditures which, it might be said, were unprecedented in this department of business — for the renewal and reconstruction of the machinery; while the state of business in the woolen and worsted industry was such as to test to the utmost the courage and capacity of the new treasurer. No man ever rose more completely to the height of a situation. He restored the Pacific Mills to their former prestige, and won for himself a name among the very first of American captains of industry. To the close of his life he retained control of the affairs of this great corporation, having the fullest confidence of the stockholders and directors. Even while he was dying it was a source of inexpressible gratification to him that he was able, though with a faltering hand, to sign what he considered the most favorable report which, as treasurer, he had ever had occasion to render. The full story of Mr. Saltonstall's business career, in all its varied aspects and with greatest amplitude of detail, would be most

instructive to the young men of the country; but our limits of space will not allow us to dwell longer upon it at this time.

Mr. Saltonstall was married in 1855 to Miss Georgiana Crowninshield, daughter of Hon. Nathaniel Silsbee, of Salem. An only child, a son named Gurdon, was born to them in 1856. In 1862 Mr. Saltonstall left Salem as a place of residence; and thereafter during the winters occupied his house on Commonwealth Avenue, Boston, one of the first houses built in that district, spending his summers on his beautiful estate in Lynnfield, on the shore of Suntaug Lake. To the inexpressible affliction of his parents, the son died in his twenty-second year. Early in his college career he had attempted a difficult canoe voyage, in which he had endured hardships and exposures which had brought on a fatal disease. After a long struggle for life, this only child of devoted parents died in the south of France in 1878.

But it is Mr. Saltonstall's relations to this school that the historian of *Technique* has chiefly to relate. Mr. Saltonstall was elected to the Corporation of the Institute of Technology in 1885, and in May, 1887, became a member of the Executive Committee. From that time onward, until near his decease, he performed a part in the support and development of this school of industrial science which it would be impossible to overstate. His knowledge of business, his mastery of affairs, would alone have made him a useful member of the Committee; but his splendid enthusiasm, his magnificent moral courage, his buoyant temper, which rose ever higher at the sight of obstacles and dangers, his uncompromising regard for justice, his sense of humor, his spirit of fun, all came in to make up that totality of faculties and qualities which rendered Henry Saltonstall an invaluable counselor. No words will enable one who has not been intimately associated with Mr. Saltonstall to understand the uplifting influence of his presence, his words, and his example.

Mr. Saltonstall's years of service as a member of the Executive Committee of the Massachusetts Institute of Technology have become a part, not only of the history, but of the present life of the school. To separate what he did and what he was from what the Institute today is, would be as impossible as for Shylock to take his pound of flesh nearest to the heart without spilling the blood. He saw the school increase from six hundred students to twelve hundred. He saw building after building rise to make the new Institute. He rejoiced in it all. Of it all he was a part. As those years went on, his

affection for and devotion to the school, which he had helped to guide through so many difficulties and helped to guard against so many dangers, grew stronger. He frequently spoke of the Institute of Technology as among his dearest interests in life; and it was with the deepest reluctance that in June, 1894, the progress of disease compelled him to relinquish his membership in the Executive Committee, though still remaining in the Corporation. On the third of December, in the same year, Mr. Saltonstall died at his Boston home, having for months borne great suffering with undaunted courage and fortitude.

AN APPARATUS FOR ILLUSTRATING PHASE-DIFFERENCES.

BY LOUIS DERR, M.A.

Read February 13, 1896.

WHEN an harmonic electromotive force is applied to a circuit of ohmic resistance R, inductance L, and capacity C, there exists in general a phase-difference θ between the electromotive force and the resulting current, whose magnitude is expressed by the equation

$$\tan \theta = \frac{Lp}{R} - \frac{1}{CRp},$$

in which p is a quantity equal to 2π times the number of alternations of the current per second. From this equation it appears that θ may be positive, negative, or zero, according to the relative magnitude of the two terms. If the circuit consists of an impedance coil, the second term is negligible, θ is positive, and the current is behind the electromotive force in phase; if the circuit contains a condenser only, the second term predominates, θ is negative, and the current is ahead of the electromotive force.

To show these and other phase-relations on a scale suited to lecture-room illustration, the apparatus here described has been devised by the writer, its operation depending on the principle that when an electric current is sent through a wire lying perpendicularly across a magnetic field a force is developed which urges the wire at right angles to both the direction of the field and the current. A powerful electromagnet is mounted on an upright stone base, and a wire is stretched across the field between its poles. At the top of the apparatus the wire terminates in the free end of a light metallic hinge, to which a small mirror is cemented. The to-and-fro vibrations of the wire may be observed by a beam of light reflected from the mirror to a screen, the hinge preventing all lateral motion and twisting. The other end of the wire carries a tuning-pin and a device providing a slight angular motion of the whole wire for adjusting the mirror.

An alternating current sent through the wire urges it alternately backward and forward, and if the tuning-pin is turned until the period of free vibration of the wire coincides with that of the current the

wire springs into vigorous and distinctly audible vibration, and the spot of light reflected from the mirror on the screen elongates into a vertical line. That this line is traced by the moving spot is easily shown by putting in the path of the reflected beam a mirror revolving about a vertical axis, and thence reflecting to the screen. On turning the second mirror the successive positions of the spot fall in different verticals, and the result on the screen is a very perfect sine-curve, a faithful representation of the vibrations of the wire. Figure 1 shows the arrangement of mirrors, using two wires.

With two such wires the observation of the phase-difference between two currents is easily made. With everything at rest, the mir-

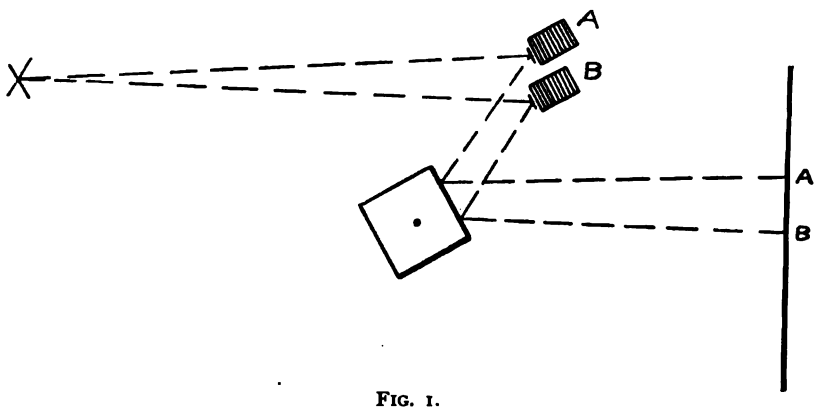

FIG. 1.

rors are adjusted until the spots of light reflected on the screen are coincident. If now the wires are connected into separate circuits carrying currents, the lines of light on the screen remain superposed, the one corresponding to the stronger current appearing slightly longer than the other. On turning the revolving mirror any phase-difference between the currents is at once shown by the horizontal displacement of the lagging curve past the other, exactly as text-book diagrams of such curves are drawn.

To observe phase-differences between voltage and current under various conditions, one wire is connected to the terminals of the given circuit through a suitable non-inductive resistance. The resulting current will then be sensibly in phase with the applied electromotive force, and the curve on the screen may be taken as representing the changes of the electromotive force itself. The other wire, shunted if necessary, carries the current to be studied. One of the curves on the screen may be colored and thus identified by putting a slip of

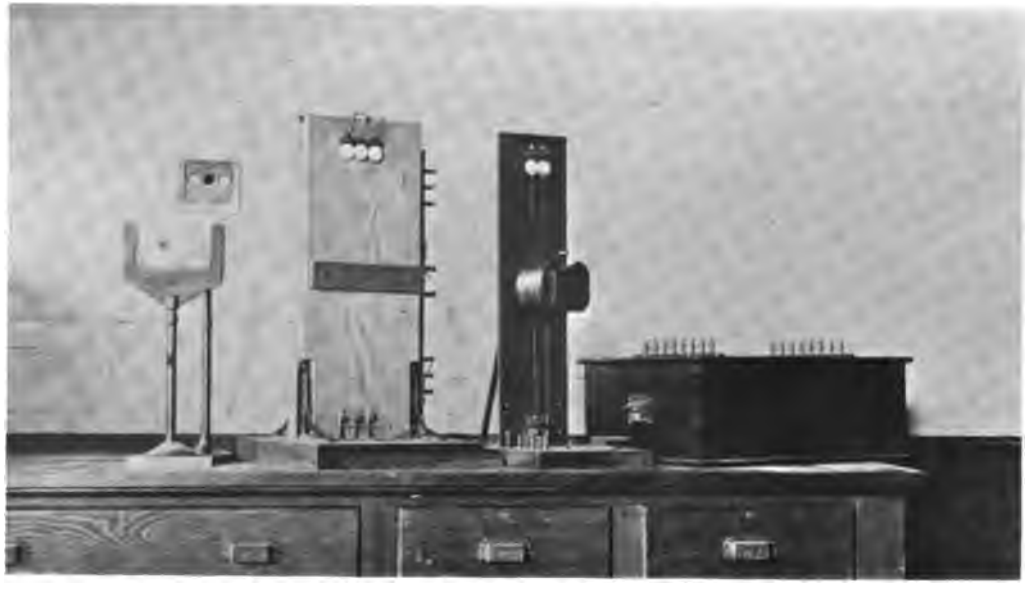

FIG. 3.

colored glass in front of the corresponding mirror. The phase-relations between voltage and current in circuits of different character may be conveniently compared by using a three-point switch and connections as shown in Figure 2, where L represents an impedance coil, R a non-inductive resistance, and C a condenser. The circuits can thus be interchanged as rapidly as desired; and the instant shifting of the curves on the screen, corresponding to the character of the circuit employed and agreeing with the conclusions of a preceding paragraph, is quite striking. With the apparatus here shown a current of one ampere in the wire and a total length of about thirty feet in the reflected beam give curves on the screen of two feet amplitude.

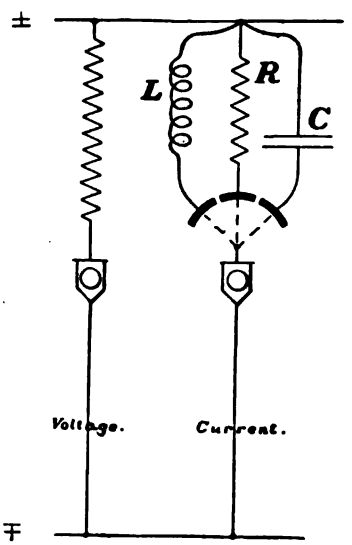

FIG. 2.

The angular relations between the currents in a polyphase circuit may be shown to an audience if the necessary number of mirrors is employed; the reactions of condenser and impedance coil upon each other in a circuit adjusted for resonance may be illustrated if a high-voltage condenser of large capacity is available; and the phase-relations between the primary and secondary voltage and current of a transformer may be demonstrated. Figure 3 shows two-wire and three-wire apparatus, together with the 17-microfarad condenser and color-screens used in the experiments. A foot rule is also photographed to show the size of the instruments. Exact dimensions are not given, as the size of every part may be varied within wide limits.

It should be stated that the results given by the apparatus in its present form are not quantitatively accurate within several per cent., especially if the currents in the wires are not truly sinusoidal.[1] The discrepancies between calculated phase-differences and those observed with the apparatus, while unfitting it for precise measurement, do not, however, interfere with its usefulness as an instrument for purposes of illustration.

ROGERS LABORATORY OF PHYSICS.
September, 1896.

[1] Thesis of Messrs. Fish and Libby, 1895.

ON THE HYDROLYSIS OF FERRIC CHLORIDE.

By H. M. GOODWIN, Ph.D.

Received August 8, 1896.

Read at the Buffalo Meeting of the American Association, September, 1896.

Introduction.

The following article contains the results of some experiments made during the summer of 1895 on the changes which take place in a neutral ferric chloride solution when suddenly diluted. I was led to this investigation during the course of some experiments on its electrical conductivity. It was observed that, when a series of measurements of the conductivity were made in the usual way in an Arrhenius cell, at a dilution of about a thousand liters ($v = 1{,}000$) a constant setting on the bridge could no longer be obtained. The conductivity slowly, but unmistakably, increased with the time, while at the next dilution ($v = 2{,}000$) this increase became very rapid. I find this phenomenon has also been observed and described in a note by Foussereau.[1] I also observed that the solution, which when first diluted was practically colorless, rapidly turned reddish yellow, deepening to a reddish brown.[2] This color reaction was no less marked than that accompanying the change in conductivity. Indeed, when 1 cc. of a 0.1-normal solution is diluted to a liter, one might hope, with a good colorimeter, to follow it colorimetrically. A 0.0001-normal solution, which was practically colorless on first dilution, became within half an hour much deeper in color than a 0.01-normal solution which had stood for days. That the changes in color and conductivity are allied phenomena was evident, and the reaction seemed so interesting that I determined to study it further. In the following experiments the velocity of the reaction taking place on diluting

[1] Foussereau, C. R., 103, 42 (1886).

[2] Since the greater portion of this paper was written an article has come to my notice in the Gazetta Chimica Italiana, 23, 1 (1895), by Antony and Giglio, in which the color phenomena of dilute neutral ferric chloride solutions are studied.

a solution of ferric chloride with varying amounts of water is followed by measuring the conductivity of the solution at different times. The reaction which probably takes place will be considered later in the light of the experimental results which were obtained.

Experimental Results.

All measurements were made in a large thermostat maintained at a constant temperature of 25° C. The variations of temperature during a run of several days' duration were not greater than 0.2°–0.3°. When a discontinuous run was made, and the temperature allowed to fall, the results are so indicated. The conductivity was measured by the usual Kohlrausch method. For the more concentrated solutions, in which the reaction could be followed at leisure, the solutions were made up and kept in glass-stoppered bottles which had previously been thoroughly steamed to dissolve out as much soluble matter in the glass as possible. When a measurement was to be made a portion was poured into the conductivity cell of the Arrhenius form. This procedure was impossible for very dilute solutions, in which the velocity of the reaction was great at the start. For this purpose I used 500 cc. wide-necked bottles, which had been previously steamed, as measuring cells; the electrodes were firmly fixed in a piece of vulcanite, which was held in position by a large rubber stopper. The capacity of this cell was determined under exactly the same conditions as regards position of electrodes, quantity of solution, etc., as in the measurements themselves. If it was desired to dilute a solution five hundred times, 499 grams of pure water were weighed out in the bottle, placed in the thermostat, and allowed to assume the constant temperature as indicated by a constant conductivity. 1 cc. of the solution, also at 25°, was then run in, at a noted time, by a carefully calibrated pipette, the bottle closed with a ground-glass stopper and vigorously shaken, the electrodes instantly replaced, and a measurement taken as quickly as possible. The operation of diluting, shaking, and making a measurement took from three quarters of a minute to a minute. The temperature of so large a mass of liquid did not appreciably change during the few instants' shaking, so that with rapid work a reliable initial measurement could be obtained within a minute after the dilution. The frequency of the readings following depends on the velocity of the reaction and the minuteness with which it is desired to follow it. For convenience, the conduc-

tivity method, when applicable, is unsurpassed for following the course of a reaction, as no further manipulation is necessary than reading the position of the minimum from time to time.

For the neutral ferric chloride solution with which the following experiments were made I am indebted to Dr. A. A. Noyes, the solution being a part of that used by him in his investigation on the "Velocity of the Reaction Between Ferric Chloride and Stannous Chloride."[1] Analysis showed the solution to be neutral and 0.303 molecular normal. It had stood over six months when analyzed, and was of a deep yellowish-red color. In what follows, the concentration of all solutions is expressed in gram molecules per liter unless otherwise stated, and the word normal is to be understood in that sense.

I give, in the first place (Table I), the results of a duplicate series of measurements of ferric chloride for concentrations from 0.101- to 0.00158-normal, the dilutions being made in the usual manner in an Arrhenius cell. The conductivity is expressed in mercury units. Nothing abnormal was noticed in these measurements, the conductivity reaching a constant value when the temperature became constant within a few minutes after each dilution. The color of the solution became fainter and fainter with each successive dilution. On attempting to make the next and all following dilutions the phenomenon already described first made itself evident.

TABLE I.

Conductivity of $FeCl_3$ at 25° C.

Dilution. v.	Concentration. $c = \frac{1}{v}$.	Molecular conductivity.	Mean.	Equivalent conductivity.
9.90	0.1010	244.3		
		244 5	244.4	81.5
19.80	0.0505	290.0		
		290.3	290.2	96.7
39.6	0.02525	339.0		
		338.8	338.9	113.0
79.2	0.01263	390.5		
		391.1	390.8	130.3
158.4	0.006315	445.2		
		444.6	444.9	148.3
316.8	0.003158	498.5		
		499.3	498.9	166.3
634.0	0.001579	545.0		
		545.6	545.3	181.8

[1] Noyes, Zeitschrift für physikalische Chemie, 16, 546 (1895).

Tables II to VII, inclusive, contain the results of measurements of the increase of the electrical conductivity with the time, for solutions varying in concentration from 0.002422- to 0.000101-normal. For solutions stronger than 0.0012-normal it was found advantageous to make the dilutions in bottles and to transfer a portion to the conductivity cell when a measurement was desired. As will be seen from the figures, the reaction did not begin with these solutions until after the elapse of a considerable time, so that the reaction could be followed at leisure. For very dilute solutions the dilution and measurements were made in the large bottles already described. It was found impossible to get reliable initial values for dilutions greater than about 0.0001-normal, as in such solutions the initial velocity of the reaction became enormous.

TABLE II.

Conductivity of $FeCl_3$, 0.002422-normal at 25°. (2 cc. of 0.303-normal diluted to 250 cc.)

Time.		Molecular conductivity.	Equivalent conductivity.	Remarks.
	h. m.			
May 24	11 45	.....	.....	Diluted.
" "	11 46	519.0	173.0	Solution slightly yellow.
" "	12 0	519.0	173.0	
" "	12 15	519.6	173.2	
" "	12 30	521.4	173.8	
" "	1 15	529.8	176.6	
" "	1 45	544.2	181.4	Color began to deepen.
" "	2 15	561.9	187.3	
" "	2 45	582.9	194.3	
" "	3 15	603.0	201.0	
" "	3 45	621.3	207.1	
" "	4 15	639.9	213.3	
" "	4 45	652.5	217.5	
" 25	12 0	787.2	262.4	
" 29	4 0	894.3	298.1	Temperature fell to room temperature.

TABLE III.

Conductivity of $FeCl_3$, 0.001211-normal at 25°. (1 cc. of 0.303-normal diluted to 250 cc.)

Time.			Molecular conductivity.	Equivalent conductivity.	Remarks.
	h.	m.			
May 23	4	0	.....	.....	Diluted.
" "	4	1	556.5	185.5	Solution nearly colorless.
" "	4	5	556.5	185.5	
" "	4	10	555.9	185.3	
" "	4	15	557.4	185.8	
" "	4	20	558.0	186.0	
" "	4	30	563.7	187.9	
" "	4	45	577.5	192.5	Color begins to increase.
" "	5	0	596.1	198.7	
" "	5	30	649.5	216.5	
" "	6	0	690.0	230.0	
" "	6	30	722.1	240.7	
" "	7	0	747.9	249 3	
" "	7	30	768.0	256.0	
" "	8	0	784.8	261.6	
" "	9	0	811.5	270 5	
" "	10	0	835.8	278.6	
" 24	5	0	901.8	300.6	Very deeply colored.
" 25	5	0	928.2	309.4	Temperature was kept at 25° only during measurements from here on.
" 29	4	0	1,011.0	337.0	
June 3	5	0	1,053.0	351.1	
" 12	3	0	1,070.0	356.6	
" 20	3	0	1,080.0	360.0	

TABLE IV.

Conductivity of $FeCl_3$, 0.000802-normal at 25°. (1 cc. of 0.303-normal diluted to 375 cc.)

Time.				Molecular conductivity.	Equivalent conductivity.	Remarks.
	h.	m.	s.			
May 30	12	0		.....	.....	Diluted.
" "	12	1	30	579.6	193.2	Solution practically colorless.
" "	12	3		579.6	193.2	
" "	12	4		579.3	193.1	
" "	12	5		580.5	193.5	
" "	12	6		581.7	193.9	
" "	12	15		589.8	196.6	
" "	12	30		633.0	211.0	Color begins to deepen.
" "	12	45		681.9	227.3	
" "	1	5		732.0	244.0	
" "	1	30		780.0	260.0	
" "	2	0		821.4	273.8	
" "	3	0		874.5	291.5	
" "	4	0		905.0	301.8	
" "	5	0		919.0	306.3	
June 1	5	30		1,009.0	336.2	Deep reddish yellow.
" 3	4	0		1,051.0	350.3	
" 12	2	15		1,103.0	367.7	
" 20	1	15		1,108.0	369.2	

TABLE V.

Conductivity of $FeCl_3$, 0.000606-normal at 25°. (1 cc. of 0.303-normal diluted to 500 cc.)

Time.		Molecular conductivity.	Equivalent conductivity.	Remarks.
	h. m.			
May 30	11 30	.....	.....	Diluted.
" "	11 31	591.6	197.2	Solution colorless.
" "	11 32	591.6	197.2	
" "	11 33	592.2	197.4	
" "	11 34	592.8	197.6	
" "	11 35	594.0	198.0	
" "	11 39	599.2	199.8	
" "	11 45	619.5	206.5	Begins to turn yellow.
" "	11 50	639.0	213.0	
" "	11 55	666.9	222.3	
" "	12 12	738.0	246.0	
" "	12 40	780.0	260.0	
" "	1 0	854.0	284.7	
" "	1 40	905.0	301.6	
" "	2 35	942.0	313.9	
" "	3 40	979.0	326.3	Deeply colored.
" "	4 37	998.0	332.5	
June 1	5 0	1,061.0	353.6	
" 3	4 15	1,090.0	363.4	
" 12	2 0	1,132.0	377.3	
" 20	1 30	1,137.0	379.0	

TABLE VI.

Conductivity of $FeCl_3$, 0.000303-normal at 25°. (5 cc. of 0.03-normal diluted to 500 cc.)

Time.		Molecular conductivity.	Equivalent conductivity.	Remarks.
	h. m.			
July 4	12 35	.....	.....	Diluted.
" "	12 36	601.5	200.5	Solution colorless. Begins to turn yellow immediately.
" "	12 37	635.7	211.9	
" "	12 39	712.8	237.6	
" "	12 40	735.6	245.2	
" "	12 45	813.0	271.0	
" "	12 50	860.0	286.6	
" "	12 55	893.0	297.7	
" "	1 0	915.0	305.0	
" "	1 10	951.0	317.0	
" "	1 20	977.0	325.7	
" "	1 50	1,019.0	339.7	
" "	2 50	1,054.0	351.3	
" "	3 36	1,070.0	356.7	
" "	4 36	1,081.0	360.3	
" "	5 5	1,085.0	361.7	
" 5	2 0	1,107.0	369.0	
" 6	1 0	1,118.0	372.7	

TABLE VII.

Conductivity of $FeCl_3$, 0.000101-normal at 25°. (1 cc. of 0.0303-normal diluted to 300 cc.)

Time.				Molecular conductivity.	Equivalent conductivity.	Remarks.
	h.	m.	s.			
July 4	1	30		...	...	Diluted.
" "	1	31	10	759	253	Solution colorless.
" "	1	31	45	819	273	
" "	1	32		837	279	
" "	1	33		885	295	Solution became perceptibly yellow.
" "	1	34		924	308	
" "	1	35		948	316	
" "	1	37		981	327	
" "	1	40		1,008	336	
" "	1	45		1,038	346	
" "	2	0		1,074	358	
" "	2	30		1,095	365	
" "	4	0		1,101	367	
" "	4	30		1,107	369	
" "	5	15		1,107	369	Solution reddish yellow.
" 5	2	15		1,110	370	
" 6	1	10		1,107	369	

The course of the reaction which here takes place and its dependence on the dilution is best seen from the curves (Figure 1) representing the results given in Tables II to VI.

Here the molecular conductivity is plotted as ordinates and the corresponding times as abscissæ. A consideration of the curves shows that:

First. The molecular conductivity of dilute solutions increases with the time.

Second. The rate of increase increases very rapidly with the dilution. These conclusions agree with Foussereau's statement, but as he gives no data a numerical comparison cannot be made.

Third. The increase in the conductivity does not begin at once on dilution, but only after the lapse of a certain time.

Fourth. The time required to start the reaction increases very rapidly with the concentration. Thus the reaction, as indicated both by increase in conductivity and change of color, begins only after the lapse of 1 minute for a 0.0006-normal solution, 15 minutes for a 0.0012-normal solution, 45 minutes for a 0.0024-normal solution.

Fifth. The time required for the solution to reach a state of equilibrium increases enormously with the concentration. Thus a 0.0001-normal solution (Table VII) requires but three hours, while a 0.0006-normal solution (Table V) requires over a week.

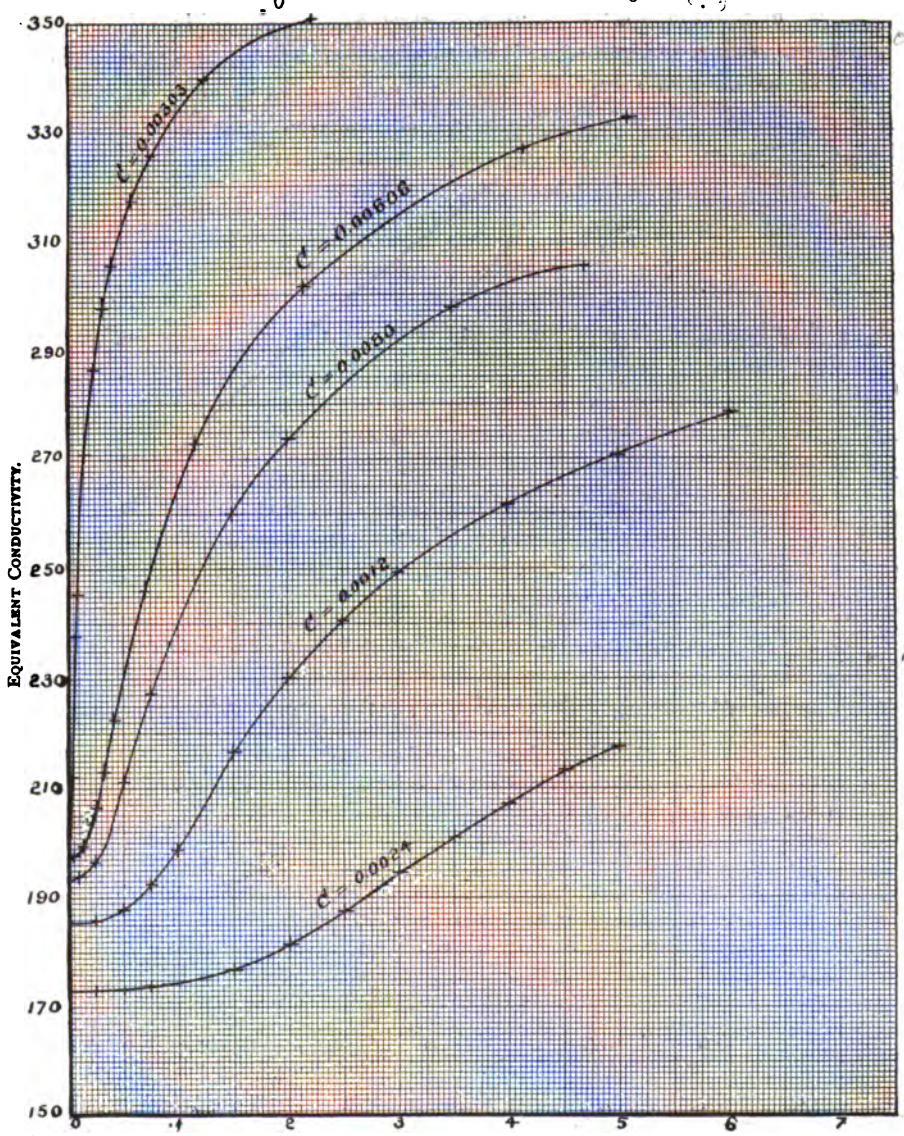

FIG. 1,

Sixth. The reaction when once started progresses slowly at first, then more and more rapidly up to a certain point where a maximum rate is reached, and then more and more slowly, until finally it ceases.

The remarkable inertia of the reaction and its great dependence

on the concentration is more strikingly shown in Table VIII, which contains measurements of still more concentrated solutions. Here it will be seen that as the concentration increases the solution remains clear and only slightly colored, and its conductivity is constant for days before any change is noticed. And here, too, another phenomenon not previously observed with dilute solutions manifests itself. The change in conductivity and color is accompanied by a turbidity of the solution, which gradually increases in the more concentrated solutions to a heavy, yellowish precipitate. I thought at first that this might be due to the action of soluble matter in the glass bottles in which the solutions were kept. I accordingly repeated the experiments, using flasks of thoroughly steamed, hard Jena glass, but with the same results. The formation of the precipitate, which is probably the oxychloride, is therefore independent of the vessel in which the solution is kept. Owing to the formation of this precipitate and resulting uncertain change in concentration of the solution, it was thought useless to follow the changes in these solutions until they reached a state of equilibrium. Only in very dilute solutions — less than 0.0025- to 0.003-normal — can this be done with any degree of certainty.

The *initial* values given in Table VIII are, however, reliable measurements of the conductivity at the respective dilutions, and fall almost exactly on the curve representing the initial values given in Tables I to VI.

TABLE VIII.

Molecular Conductivity of $FeCl_3$ at 25°.

Concentration.	$t = 0$.	$t = 1$ day.	$t = 2$ days.	$t = 3$ days.	$t = 4$ days.	$t = 14$ days.
0.0303	327.6 Clear.	327.6 Clear.	327.0 Clear.	327.9 Clear.	328 2 Clear.	390.0 Very turbid.
0.01515	377.7 Clear.	376.2 Clear.	377.1 Clear.	377.1 Clear.	392.4 Slightly turbid.	..... Very turbid.
0.00758	432.3 Clear.	432. 3 Clear.	504.9 Very turbid.	532.5 Very turbid.	563.4 Very turbid.	....
0.00379	485.4 Clear.	636.0 Slightly turbid.	708.0 Turbid.	729.0 Turbid.	....	....
0.00189	534.3 Clear.	810.0 Clear.	855.0 Clear.	882.0 Clear.	..... Clear.	..... Clear.

Explanation of Results.

The following explanation of these results, which is the most plausible which has suggested itself, is the outcome of the discussion of the preceding data with my friend, Dr. A. A. Noyes, whose valuable suggestions it is a pleasure to acknowledge here.

Ferric chloride is, as is well known, more or less hydrolyzed in aqueous solution, the amount of hydrolysis depending on the dilution. When a concentrated solution in which the hydrolysis is small is

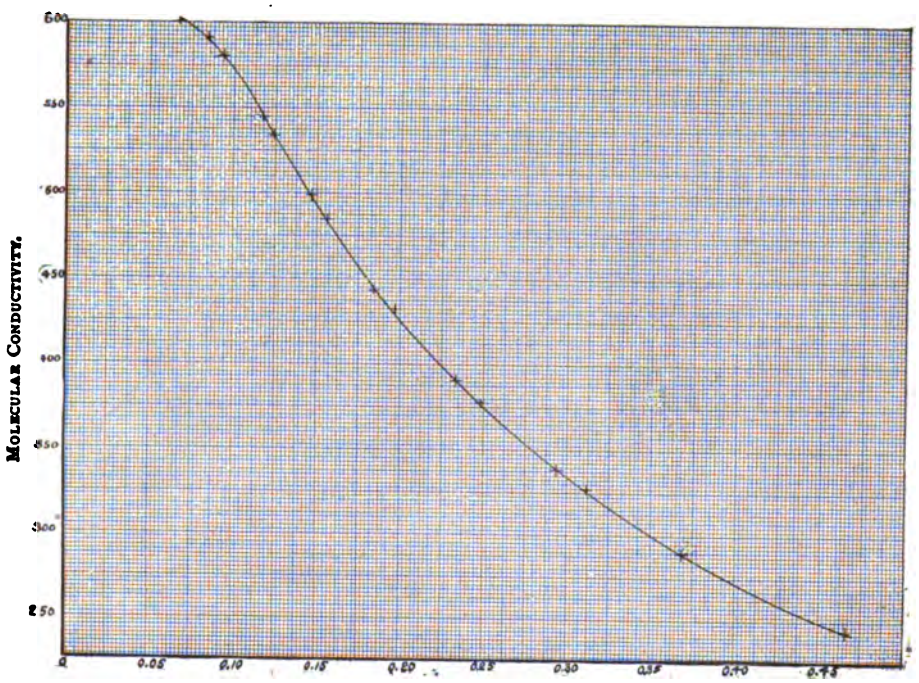

Fig. 2.

suddenly diluted, instantly and simultaneously with the increase in electrolytic dissociation further hydrolytic dissociation takes place, the ferric ions uniting with the hydroxyl ions of the water. It will be seen later, however, that there is good reason to believe that this hydrolysis does not result in the formation of electrically neutral ferric hydrate (FeO_3H_3), which is probably a strongly dissociated base, but in the formation of the bivalent ion FeOH resulting from its dissociation. That is to say, the *a priori* not improbable assumption is here made that, as in the case of polybasic acids the successive

hydrogen ions dissociate less and less readily, so in the case of this polyacidic base the first and also the second hydroxyl ion splits off in dilute solution nearly completely, and it is only the bivalent basic ion FeOH which is slightly enough dissociated to give rise to hydrolysis. As already stated, an *a posteriori* justification of this assumption is furnished by the experiments themselves.

The result on first diluting the solution is, therefore, that the hydrolytic reaction $\overset{+++}{Fe} + H_2O = \overset{+}{FeOH} + \overset{+}{H}$ takes place, and the conductivity of the solution is thereby increased by an amount proportional to the difference of the velocity of migration of the hydrogen and ferric ions. Consequently the initial electrical conductivity must increase more rapidly than can be accounted for by increasing electrolytic dissociation alone. That this is the case is seen by reference to Figure 2, in which the initial values of the equivalent conductivity are plotted as ordinates and the cube root of the concentrations ($\sqrt[3]{c}$) as abscissæ. If we further assume that the $\overset{+}{FeOH}$-ions are colorless, or nearly so, then on first diluting a solution the color will simply become fainter and fainter in proportion to the decrease in concentration.

To explain now the further increase of conductivity with the time and the attendant change in color of the solution, we have only to assume that the deeply colored colloidal ferric hydrate described by Graham[1] is gradually formed according to the reaction

$$x\mathrm{Fe(OH)_3} = (\mathrm{FeO_3H_3})_x,$$

or what amounts to the same thing:

$$x\overset{+}{FeOH} + x2\overset{-}{OH} = (\mathrm{FeO_3H_3})_x.$$

It is assumed, for simplicity, that the colloidal hydrate is a polymer of the theoretical formula, although the experiments of Maguier de la Source[2] and Sabanejeff[3] indicate that the probable composition is $FeCl_3x(FeO_3H_3)$, x being very large, however, compared to unity. This reaction is, for the dilutions investigated, practically non-reversible. Krecke[4] found that for solutions less than 1 per cent. this was the case.

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[1] Graham, Liebig's Annalen, 121, 46.
[2] C. R., 90, 1352.
[3] Sabanejeff, Chemisches Centralblatt, 1, 11 (1891).
[4] Krecke, Jour. pract. Chem. (2), 3, 286.

Since the equilibrium of the true hydrolytic reaction is determined by the concentration of the $Fe(OH)_3$ molecules or of the $\overset{+}{Fe}\overset{+}{O}H$-ions, and not of the polymerized molecules, as fast as the former is diminished by the colloidal reaction further hydrolytic dissociation must take place, and hence the conductivity must increase. Moreover, since the velocity of the colloidal reaction depends primarily on the amount of hydrolyzed salt, it too must increase with the dilution, as was also found to be the case.

The remarkable initial lag in the reaction is most probably due to the fact that the reaction product itself, the colloidal hydrate, accelerates the reaction in the same way, perhaps, that the velocity of crystallization from supersaturated solutions increases as the number of crystal centers themselves increase. Consequently the velocity becomes at first greater and greater as the reaction progresses, owing to the increase in the amount of colloidal ferric hydrate present, but later reaches a maximum, and finally decreases, owing to the diminution in concentration of the substance undergoing the reaction (the FeO_3H_3 or FeOH).

The fact that the reaction takes place so much more rapidly in dilute solutions is due to the much larger proportion of FeOH or FeO_3H_3 which these contain. The speed in dilute solutions is, moreover, also greatly increased by reason of the fact that the greater amount of colloidal ferric hydrate produced from the cause just mentioned, itself enormously accelerates the reaction; for the acceleration of this reaction by any cause is itself a secondary cause of a further acceleration.

Calculation of the Hydrolytic Dissociation.

If the preceding explanation of the time increase of the conductivity of dilute solutions of ferric chloride is true, it is clear that we must distinguish between the initial and final value of the hydrolysis in computing its value. Reasoning from the results obtained, it would seem probable that with concentrated solutions the colloidal reaction would practically begin only after an infinite time. To test this conclusion, I made up and measured a fresh solution of neutral ferric chloride, as follows: An approximately 0.03-normal solution, made up by dissolving 2.5660 grams of especially sublimed ferric chloride in 500 cc. of water. The solution was of a clear light-yellow color.

Subsequent analysis showed the solution was 0.03101-normal with respect to iron, and 0.03084-normal with respect to chlorine. It was assumed neutral and equal to 0.0309-normal.

The conductivity of this solution and of a portion diluted ten times was measured within ten minutes after making up. The values obtained were $\mu = 324.0$ and $\mu = 499.5$, respectively, whereas the values interpolated from Figure 2 for the same concentrations were $\mu = 323$ and $\mu = 498$. The agreement is complete. It is proved, therefore, that there was no appreciable amount of colloidal hydrate in the original 0.3-normal solution with which the preceding experiments were made, although it had stood over a year, and that the values given in Table I truly represent the initial conductivity at the given dilutions.

Let us now suppose that at a given dilution one molecule of ferric chloride is α per cent. electrolytically dissociated according to the reaction

$$FeCl_3 \rightleftarrows Fe + 3Cl,$$

and β per cent. hydrolytically dissociated according to the reaction

$$FeCl_3 + H_2O = \overset{+}{Fe}\overset{+}{O}H + \overset{+}{H} + 3\overset{-}{Cl}.$$

The solution will therefore contain $1 - \alpha - \beta$ molecules of undissociated ferric chloride, α ferric ions, and β FeOH-ions. A knowledge of α and β will, therefore, completely determine the nature of the solution. Of the molecular complexes present, only the ions contribute to the conductivity of the solution. If u, u', u'', and v are the velocities of migration of the ferric, hydrogen, $\overset{+}{Fe}\overset{+}{O}H$, and chlorine ions, respectively, then the equivalent conductivity of the solution is given by

$$\mu = \alpha(u + v) + \beta\left(\frac{2u'' + u' + 3v}{3}\right). \qquad 1)$$

On the other hand, the total number of molecular complexes i will determine the lowering of the freezing point of the solution; *i.e.*,

$$\begin{aligned} i &= 1 - \alpha - \beta + 4\alpha + 5\beta. \\ &= 1 + 3\alpha + 4\beta. \end{aligned} \qquad (2)$$

We have here two independent equations for determining α and β, provided μ and i are measured and the remaining quantities in (1) are known. Of these, the velocities of migration of the ferric and of

the FeOH-ions have not been determined. We may, however, by analogy, and with the help of the principle that the rates of migration of all such ions are of the same order of magnitude, estimate their values with sufficient accuracy. We will assume them equal to each other, and that the numerical value at 25° is 50.[1] Taking Ostwald's values of 70 and 325 for chlorine and hydrogen, respectively, (1) may be written

$$\mu = 120\alpha + 212\beta, \qquad (1a)$$

and

$$\alpha = \frac{i - 1}{3} - \frac{4}{3}\beta. \qquad (3)$$

Hence, solving for β:

$$\beta = 2.31\left(\frac{\mu}{120} - \frac{i - 1}{3}\right). \qquad (4)$$

α and β can be computed by this method only for those concentrations at which both freezing point and conductivity measurements are possible. It will be seen, however, from the following table that the values of α and β computed in this way give for the total dissociation of the salt, *i. e.*, $\gamma = \alpha + \beta$, very nearly the same values as found for barium chloride, a typical binary salt. I have therefore calculated β for the dilute solutions where reliable freezing-point data are not obtainable, on the assumption that the amount of undissociated ferric chloride present at each dilution is the same as the amount of undissociated salt in the case of the bivalent chlorides. Substituting $\alpha = \gamma - \beta$ in (1*a*), we get $\mu = 120\gamma + 92\beta$, or $\beta = \frac{\mu - 120}{92}\gamma$, from which β is calculable at once by giving γ the values of $\frac{\mu}{\mu_\infty}$ for barium chloride.

For measurements of the lowering of the freezing point I have to thank the kindness of my friend, Dr. Harry C. Jones, who measured several solutions, made up from my stock solution, by his well-known method.[2] His results are given in Table IX.

[1] The mean of the velocities of migration of copper, zinc, and magnesium ions are about two units greater than that of sodium from Kohlrausch's values of μ_∞ for these sulphates of these metals; and as, so far as the meager measurements on ferrous chloride and sulphate show, the ferrous ion (and, presumably, also the ferric ion) moves even slower than the above-mentioned bivalent ions, we may assume as a probable upper limit for velocity of migration of the ferric ion a value a little greater than that of sodium. The latter at 25° is 49, hence the approximate value 50 assumed.

[2] Zeitschrift für physikalische Chemie, 11, 529 (1893).

TABLE IX.

Lowering of Freezing Point of $FeCl_3$.

Grams in liter.	Concentration. (Molecular normal.)	Observed lowerings.	Gram molecular lowering.
1.7858	0.0110	0.0808°	7.35
3.9369	0.0242	0.1670°	6.90
5.990	0.0369	0.2455°	6.65
8.9291	0.0550	0.3434°	6.24
10.7555	0.0663	0.4101°	6.18
13.3936	0.0825	0.4928°	5.97

From these values I obtained, by graphic interpolation, the values of the molecular lowering M, and hence the values of $i = \frac{M}{1.88}$, for the dilutions indicated in Table X. Column 1 contains the concentration in gram-equivalents, Column 2 the value of i, Column 3 the equivalent initial conductivity μ_{t_0}, Column 4 the value of $\frac{\mu}{\mu_\infty}$ for barium chloride, Columns 5, 6, and 7 the values of α, β, and $\gamma = \alpha + \beta$, computed as explained above. In Column 8 is given the value of β', computed on the assumption that the hydrolysis takes place according to the reaction $FeCl_3 + 3H_2O = Fe(OH)_3 + 3\overset{+}{H} + 3\bar{Cl}$, in which case equations (3), (4), and (5) become, respectively,

$$\alpha = \frac{i - 1}{3} - 2\beta,$$

$$\beta = \frac{1}{1.29}\left(\frac{\mu}{120} - \frac{i - 1}{3}\right),$$

$$\beta' = \frac{\mu - 120\gamma}{275}.$$

The figures can be regarded as approximate only, being undoubtedly subject to an error of several per cent. They indicate, however, the probable way the true *hydrolysis* takes place, and give an approximate measure of its amount.

TABLE X.

Equivalent concentration.	i.	μ_{t_0}.	$\frac{\mu}{\mu_\infty}$	α.	β.	γ.	β'.
0.30	3.084	82	70.5	73	—3	70	— 1
0.15	3.394	97	77.2	77	2	79	+ 1
0.075	3.669	113	79.4	74	11	85	4
0.030	3.916	136	86.6	50	37	87	12
0.015	.....	155	88.2	35	53	..	18
0.0075	.....	171	90.8	24	67	..	22
0.0030	.....	190	94.2	10	84	..	28
0.0015	.....	199	95.8	5	,91	..	31

Thus inspection of the values of β' shows that, on the assumption that the hydrolyzed hydrate is undissociated, the hydrolysis even in a 0.0015-normal solution is only 31 per cent., and that it becomes nearly constant, or increases only slowly with the dilution, a conclusion which is absurd. On the other hand, if we assume the hydrolysis to take place according to the reaction

$$FeCl_3 + H_2O = \overset{+}{Fe}\overset{+}{O}H + \overset{+}{H} + 3\bar{Cl},$$

the hydrolytic dissociation, which is practically zero for a 0.3 equivalent normal solution, rapidly increases with the dilution, as we should expect, becoming practically complete at a dilution something beyond 1,000 liters. That the effect of the colloidal reaction is to remove the FeOH-ions from the solution, according to the reaction assumed, is shown by the fact that the *final* values of the conductivity (see Tables IV to VII) after the colloidal hydrate has formed become as great as 370, *i. e.*, they approach, and nearly reach, the value 395 of μ_∞ for hydrochloric acid. The value of β' calculated for this final value of the conductivity is about 93 per cent., showing that 93 per cent. of the ferric ions have been removed from the solution; in other words, that all of the hydrolyzed salt (91 per cent.) present on first dilution as $\overset{+}{Fe}\overset{+}{O}H$-ions has gone over into the colored colloidal molecular complex.

Antony and Giglio, in the paper already referred to at the beginning of this paper, have studied the change between the initial and

final condition of dilute ferric chloride solutions by comparing colorimetrically the intensity of blue color produced when potassium ferrocyanide was added to the solutions before and after the colloidal reaction had taken place. As their solutions were allowed to assume their final condition at about 12° C., and as the colloidal formation increases very rapidly with the temperature, a comparison of their values with the above results is impossible. Thus they found a solution 0.00005-normal to be completely changed to colloidal hydrate after forty-eight hours. Table VII shows this to be practically the case with a 0.0001-normal solution at 25° after three hours.

ROGERS LABORATORY OF PHYSICS,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
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ON AN IMPROVEMENT IN THE SEDGWICK–RAFTER METHOD FOR THE MICROSCOPICAL EXAMINATION OF DRINKING WATER.

By DANIEL D. JACKSON, S.B.

Received September 24, 1896.

THE microscopical examination has assumed an important rôle in the regular analysis of drinking water since the discovery that many of the disagreeable tastes and odors often met with in waters exposed to the sunlight are due to the presence of certain minute plants or animals. Besides this important feature, the results obtained by the microscope often throw a considerable light upon the character of the organic matter contained in the water.

The gradual development of the microscopical examination of water and the improved methods employed during recent years are fully described by Professor William T. Sedgwick in "A Report of the Biological Work of the Lawrence Experiment Station."[1] The method finally decided upon, and which has come to be generally known as the Sedgwick-Rafter[2] Method, has been in use in the regular examinations of the water supplies of Massachusetts by the State Board of Health since November 6, 1890. Since that time over 11,000 quantitative microscopical analyses of water have been made in the State Laboratories at the Massachusetts Institute of Technology.

Briefly, the method employed is as follows: A definite quantity of water (usually 250 cc. for a surface water) is filtered in an ordinary chemical filter funnel through a small quantity of clean Berkshire sand. The sand selected is that which passes through a 60-mesh sieve, and will not pass through one having 120 meshes to the inch.

The organisms remain behind on the surface of the sand, while the water passes through a hole in the rubber stopper at the bottom

[1] Report of Massachusetts State Board of Health, 1890, Part II, page 792.

[2] "Microscopical Examination of Potable Water," by George W. Rafter, Van Nostrand Science Series, 1892.

of the funnel. The hole is covered by a piece of fine bolting cloth to keep the sand in place. After the water has entirely filtered through, the sand is washed down into a test-tube by 5 cc. of water free from organisms.

After shaking thoroughly, the water containing the organisms is quickly decanted from the sand into another test-tube. The micro-organisms are then thoroughly distributed by blowing into the water through a pipette, and 1 cc. is taken for examination and placed in a covered cell such as is shown at the bottom between the two filter racks in the accompanying illustration.

The cell is 50 mm. long by 20 mm. wide, and is everywhere just 1 mm. deep. The microscope is graduated so that each field examined equals 1 sq. mm., and as the cell is 1 mm. deep, a cubic millimeter of water is examined in each field. Twenty such fields are examined, and if the amount originally taken is 250 cc., the sum total of the organisms found will be the number in 1 cc. of the water; for $\frac{250}{5}$ = 50 cc. is the amount represented by the entire contents of the cell, and $\frac{20}{1000} = \frac{1}{50}$ equals the fraction of the contents examined.

Mr. G. N. Calkins, in a paper on "The Microscopical Examination of Water,"[3] gives a detailed description of the Sedgwick-Rafter Method, and of the possible sources of error which may enter into the microscopical analysis by this method.

Mr. Calkins says: "The sloping sides of a glass funnel offer a surface for the settling of organisms, and the error arising in this way may be considerable. A water free from amorphous matter and zoöglœa will filter very accurately, but a water containing these gives opportunity for error." This is undoubtedly due to the jelly-like character of the zoöglœa, and to the fact that, while adhering to the funnel sides itself, it also retains with it other organisms.

It has been the experience of the writer that not only does amorphous matter and zoöglœa readily adhere to the sides of the ordinary glass filter funnel, but the same is true of the gelatinous growths of the Cyanophyceæ and of the flocculent threads of Crenothrix.

In order to obviate this source of error as far as possible, considerable time and attention have been expended upon the construction of a new glass filter funnel which should offer to the organisms during filtration the minimum amount of surface friction.

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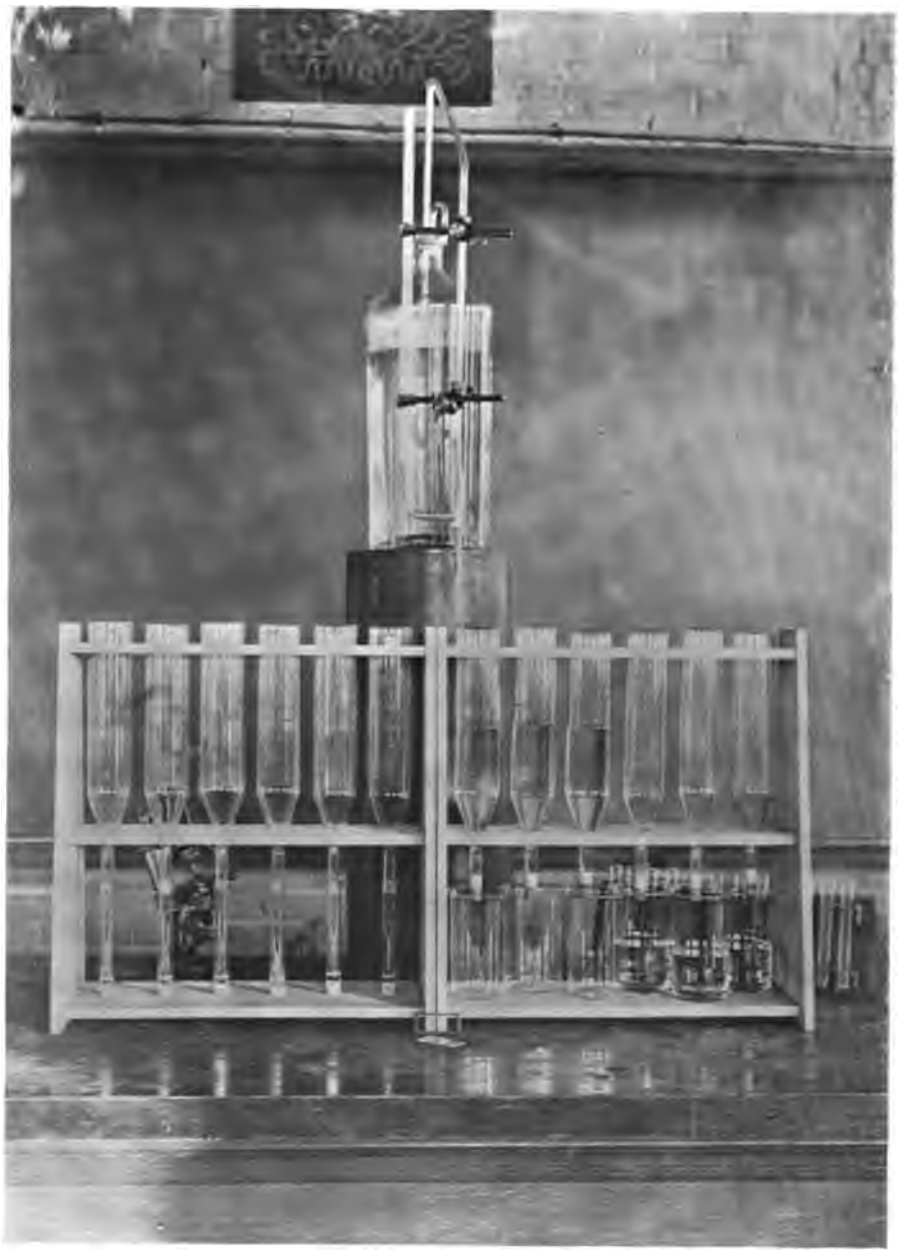
[3] Report of Mass. State Board of Health, 1891, p. 395.



IMPROVED APPARATUS FOR SEDGWICK-RAFTER METHOD.

It was found that the bore of the filter regulated to a large extent the rate of filtration. If the narrow tube at the bottom of the filter is increased in size, the surface of the sand in contact with the water is naturally increased and the rate of filtration is more rapid. With increased rapidity of filtration comes a diminished efficiency of the filter. On the other hand, if the bore is made too small, the rate of filtration is so slow as to entail a serious loss of time.

The filters shown in the accompanying photograph are those finally decided upon as being the most efficient. They are arranged in sets or "batteries" of six, in order to be easily handled, but each funnel can be removed from the rack when necessary. The inside diameter of the top of the funnel is 2 inches, the distance from the top to the beginning of the slope is 9 inches, and the length of the slope is 3 inches. The tube of small bore at the bottom is $2\frac{1}{2}$ inches long and $\frac{1}{2}$ inch in inside diameter.

The funnel should be made of comparatively thin glass, so that after the small tube is joined to the bottom annealing can be effectively accomplished. The capacity is such that 500 cc. of water may be filtered at once.

A rubber stopper with a small hole through the center is tightly fitted to the bottom of each filter funnel, so that no air space remains between the rubber and the glass. Over the hole in the rubber stopper a circular piece of fine, wet bolting cloth is placed, and on this is poured Berkshire (or quartz) sand to the depth of about three quarters of an inch. This sand should be previously selected as before described. The tube at the bottom is made long enough so that when the water is poured in the sand will not rise to the sloping sides of the funnel and become lodged there. These sloping sides should be kept clean and bright, so as to offer the least possible resistance.

After the water to be examined has passed through the filter, the beaker at the bottom is removed. The rubber stopper is then carefully taken from the lower end of the funnel so as not to disturb the wet sand, and a test-tube is quickly placed in position as shown in the filters of the left-hand rack. The arrangement shown above the filters is now used to deliver 5 cc. of distilled water into each funnel, and at the same time to wash the sand and collected organisms into the test-tubes below. Beyond this point the procedure is as before described.

In the analyses of waters by the use of the new filter funnels, con-

siderably higher results are often obtained. This is especially noticeable in waters containing a large amount of adhesive material, as is illustrated by the accompanying table.

The new filter funnels have the advantage over the old funnels in neatness, compactness, and portability. The rate of filtration is more uniform, and the results obtained more accurate. The new funnels were put into active service in the regular microscopical examinations for the Massachusetts State Board of Health on December 1, 1895, and since that time they have been used successfully for the quantitative microscopical examination of more than seventeen hundred samples of water.

NOTE. — At the request of Professor Sedgwick, the writer has recently made numerous experiments upon the use of the centrifuge in the microscopical analysis of drinking water. Its employment for this purpose was suggested by Dr. C. S. Dolley's valuable paper on "The Planktonokrit, a Centrifugal Apparatus for the Volumetric Estimation of the Food-Supply of Oysters and Other Aquatic Animals."[1] The results thus far obtained have been more satisfactory than those obtained by the sand filter above described when delicate infusoria and rotatoria are present, but with revolutions up to 2,000 per minute, poor results were obtained if Cyanophyceæ chiefly were present. This was especially the case with Anabæna, Clathrocystis, and Cœlosphærium. The experiments will be continued.

[1] Proceedings of the Academy of Natural Sciences of Philadelphia, May, 1896.

Fil

Chem
Biolo
Date
Date
Quan

DIATO
Aster
Cerat
Cocc
Cyclo
Cymb
Diato
Epith
Fragi
Gomp
Gram
Melo
Meri
Navi
Nitz
Pinn
Steph
Surir
Syne
Tabe

CYANO
Anab
Apha
Chro
Clath
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Oscil

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EXPERIENCE WITH THE SEDGWICK-RAFTER METHOD AT THE BIOLOGICAL LABORATORY OF THE BOSTON WATER WORKS.

By GEORGE C. WHIPPLE, S.B.,

Received October 2, 1896.

In connection with Mr. D. D. Jackson's paper on "An Improvement in the Sedgwick-Rafter Method of Microscopical Examination of Drinking Water,"[1] it may be interesting to note some experiences with that method at the Biological Laboratory of the Boston Water Works.

The Sedgwick-Rafter Method has been used in the Boston Water Works Laboratory at Chestnut Hill Reservoir since its establishment in 1889, and from that time to the present more than 19,000 quantitative microscopical examinations of water have been made. Most of the samples examined have been those collected from the streams, storage reservoirs, aqueducts, and service pipes of the water supply, but many examinations were made in connection with the filtration experiments conducted during the years 1891 to 1894. The character of the samples has therefore varied over a wide range, from waters free of microscopical organisms to those rich in algæ and infusoria. In all this varied work the method has seldom failed to give trustworthy record of the animal and plant forms present, and the information thus obtained concerning the condition of the water has been of material assistance to the superintendent in the management of the supply.

In common with almost all analytical processes, the Sedgwick-Rafter Method involves some sources of error. These have been carefully studied at various times in the Boston Water Works Laboratory in order to determine the precision of the method as ordinarily used. In the main, the results of the experiments made by

[1] This volume, pp. 271–274.

the writer have corroborated those obtained by Mr. Gary N. Calkins[1] in 1892, but in some respects they have been different.

The most important errors in the method are those involved in the concentration of the sample. They may be designated as follows:

1. The Funnel Error, or error caused by the organisms adhering to the sides of the funnel.

2. The Sand Error, or error caused by the organisms passing through the sand.

3. The Decantation Error, or error caused by the organisms adhering to the particles of sand and by the water used in washing the sand being held back by capillarity during the process of decantation.

The funnel error varies greatly, according to the character of the water filtered. It is highest in the case of samples rich in Cyanophyceæ and "amorphous matter." These being of a somewhat gelatinous nature adhere readily to the glass, making a rough surface on which other organisms lodge. If the funnel is wet when the sand is put in, some of the sand grains are also liable to adhere to the glass walls of the funnel; careful manipulation, however, will avoid this. Samples which filter slowly, and which for that reason give the organisms good opportunity to settle upon and become attached to the glass, show the greatest funnel errors, and indeed we may almost say that the funnel error is proportional to the time of filtration.

By filtering a sample in the usual manner, and afterwards washing the sides of the funnel with distilled water and ascertaining the number of organisms thus washed from the glass, Mr. Calkins found that the funnel error varied from 0.09 per cent. to 1.9 per cent., the average being 0.3 per cent. Similar experiments made by the writer have given somewhat larger errors than these, the average for twenty-one representative samples being 0.96 per cent. for the organisms and 2.9 per cent. for the amorphous matter. The greatest error found during the experiments was 11.3 per cent. for the organisms and 16.3 per cent. for the amorphous matter, but not infrequently the errors exceed even these figures. By employing forced filtration (*i. e.*, using the aspirator), and thus lessening the time required for the water

[1] Calkins, Gary N. "The Microscopical Examination of Water," Massachusetts State Board of Health. 23d Annual Report.

to pass through the sand, the average funnel error was reduced to 0.24 per cent. for the organisms and 0.8 per cent. for the amorphous matter. Forced filtration, however, has certain objections, and is not ordinarily advisable. The best method of minimizing the funnel error appears to be the use of tubular funnels, like those designed by Mr. Jackson. Funnels of this kind are now in use at the Boston Water Works Laboratory. Besides having the advantage of greater efficiency, they are neater in appearance, occupy less room, and are more conveniently handled.

The amount of the sand error depends upon the character of the organisms, upon the size of the sand grains and the depth of the sand. In selecting a sand to be used, two opposing conditions must be adjusted. The sand must be fine enough to form an efficient filter, and yet the grains must be large enough to settle readily in the decantation tubes. Experience has shown that for the samples received at the Boston Water Works Laboratory a sand having the following mechanical analysis satisfactorily fulfills the conditions:

Sieve marked.	Size of separation of this sieve. (Millimeters.)	Quantity of sand passing. (Per cent. of total weight.)
40	0.38	100
60	0.28	80
80	0.20	60
100	0.16	22
120	0.14	4

According to the nomenclature of the Massachusetts State Board of Health, this sand has an "effective size" of 0.15 mm. and a "uniformity coefficient" of 1.33. As to the amount of sand necessary, numerous experiments have shown that if the depth is less than 1.5 cm. the sand error is likely to be large; but with depths greater than 2 cm. the error is practically independent of the depth. In actual practice, using the sand above referred to, the error from organisms passing through the filter ought not to exceed 2 per cent., unless the samples contain organisms which are very minute. Most of the organisms which pass through the sand do so during the early part of the filtration, before the sand has become compacted. If, before the sample

is poured into the funnel, the sand is first compacted by rapidly passing through it some distilled water, using the aspirator to increase the pressure, the sand error may be much reduced.

The decantation error is one of considerable importance, depending to a great extent upon care in manipulation. It arises from the fact that when the attempt is made to separate the organisms from the sand by agitating with distilled water in one test-tube and rapidly decanting into a second tube, some of the organisms remain behind attached to the sand grains.

Mr. Calkins, in his experiments, first washed the sand with 5 cc. of distilled water and decanted, then rewashed with 5 cc. and decanted into a second tube, the number of organisms found in the second washing being taken to represent the decantation error. In this way he observed errors varying from 1.5 to 15.5 per cent., the average being 7.5 per cent. In the writer's experiments the sand was washed first with 3 cc. and then with 2 cc. of distilled water, both portions being decanted into the same tube, experience having shown that this double washing is more effective in cleaning the sand. The sand was then rewashed with 5 cc., which was decanted into a separate tube and examined to determine the decantation error. The results showed errors ranging from 0.1 to 12.0 per cent. for the organisms and 0.5 to 6.9 per cent. for the amorphous matter. The average of twenty-four observations gave 2.5 per cent. for the organisms and 3.0 per cent. for the amorphous matter, figures which are noticeably lower than those obtained by Mr. Calkins.

There is another source of error in the decantation of a sample which more than offsets the one just mentioned, and which has not generally been taken into account; it tends to give results which are too high. It is caused by the fact that some of the distilled water used in washing the sample is left behind in the sand and on the walls of the test-tube, so that the organisms when decanted receive too high a degree of concentration, for it has been found that the sand retains a larger percentage of water than of organisms. To avoid this error as much as possible, the washing of the sand should take place immediately after the sample has filtered, and the decantation tubes should be used moist instead of dry. The amount of this error is likely to reach 5 or even 10 per cent. unless great care is used in manipulation.

Very frequently samples are received at the laboratory which are

so filled with organisms or with amorphous matter that filtration is effected with great difficulty. The sand becomes clogged, and a dense scum is formed, almost if not quite impervious to water. When this occurs it is necessary either to stir the sand from above or to connect the lower end of the funnel with an aspirator, or filter pump. There are objections to both these proceedings, but the writer believes the latter to be by far the better one. It increases the sand error but little, and by lessening the time of filtration decreases the funnel error materially. Indeed, so great is the improvement in this respect, that the aspirator might be recommended for general use were it not for the danger of delicate organisms being crushed on the sand by the increased pressure. As it is, its use should be restricted to cases of emergency where it is necessary to overcome the clogging of the sand, or when for some reason it is desired to effect a rapid filtration. For these purposes the aspirator forms a valuable part of the apparatus.

In order to determine the comparative effect of stirring the sand and of using the aspirator, six samples, differing widely in the number and character of their contained organisms, were filtered: first, by gravity without stirring; second, by gravity, the sand being stirred; and third, by using the aspirator. The following average sand errors were obtained:

	Method of filtration.	Percentage sand error.
1.	Gravity without stirring	1.3
2.	Gravity, the sand being stirred . . .	2.1
3.	Using the aspirator	1.4

Thus it will be seen that stirring the sand almost doubles the sand error, while the use of the aspirator increases it but slightly.

The reduction of the funnel error when the aspirator is used is shown by the following table:

Method.	Number of examinations.	Average time of filtration. (Minutes.)	Percentage Funnel Errors.	
			Organisms.	Amorphous matter.
Gravity	9	76	0.96	2.9
Aspirator	11	4	0.24	0.8

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

VI.

Received June 12, 1896.

Steam and Hydraulics.

Description and Results of a 50-hour Test made on Thursday, Friday, and Saturday, May 7, 8, 9, 1896, at the West End Street Railway's Power Station, near Sullivan Square, Charlestown, Mass.

This test was made by ninety students of the senior class of the Massachusetts Institute of Technology as a part of the regular work of the Engineering Laboratories, and was under the direction of the instructing staff of the laboratories.

Through the courtesy of Mr. C. F. Baker, master mechanic of the road, excellent opportunities to collect instructive data were given us.

The 50-hour run was divided into five watches of ten hours each, eighteen students working on each watch.

The object of the test was to determine the evaporation of the boilers per pound of coal, the coal for the plant per indicated horse power of the main engines, and also the coal per kilowatt and per electrical horse power.

Besides the observations needed to calculate the above much other data of great value was obtained. As there were something like 20,000 observations, or about 80,000 figures, taken during the test, it was thought advisable to print only the totals and averages of the different readings.

DESCRIPTION OF PLANT.

Steam is supplied by three Babcock & Wilcox boilers, each of 500 nominal horse power (A. S. M. E. rating).

These discharge their gases into an inclined brick flue about 35 feet long at the back of the boilers. This flue leads either into a Green economizer and from thence to the stack or into a straight flue by the side of the economizer also leading into the stack. By means of dampers the gases can be turned through either of these passages.

Boilers No. 1 and No. 2 are set without any space between them. Between Boilers No. 2 and No. 3 there is a space of about four feet.

The steam piping is so arranged that either Boilers No. 1 or No. 2 can supply Engine No. 1, while Boiler No. 3 supplies Engine No. 2, or the entire battery can be made to deliver into the main.

During the test Boiler No. 1 was shut down, two boilers being all that are needed to do the work.

The stack into which these exhausted is 200 feet tall, with an internal diameter of core of 10 feet.

The engines are Allis-Corliss cross-compound, with independent jet-condensing pumps.

The parts of the engine are so designed that either cylinder can be run at 1,000 I. H. P. As either side can be made to run the engine there is but little loss of running time on account of repairs.

Engines No. 1 and No. 2 are 26, 50 x 48, and run at a speed of about 90 revolutions per minute. The main engines and air-pump engines were built by E. P. Allis, of Milwaukee.

The fly wheel of each engine is built up of mild steel plates bolted to a cast-iron hub, the whole weighing something over 40 tons.

The generator is of the multipolar direct connected type, and was built by the General Electric Company. It is known as an M. P. 10–800–90, contains 10 poles, and is of 800 kilowatt nominal capacity at 90 revolutions.

It is designed to give 500 volts at no load, and is over compounded to give 550 volts at full load when delivering 1,450 amperes.

The switchboard is of the General Electric type, with eight feeder panels and four generator panels.

Steam is taken by each engine through a Stratton separator located beneath the engine. The drip from the separator is run through a coil of pipe in the first receiver, and thence trapped directly into the suction of the feed pump.

There is a small amount of drip from the working side of the receiver which is thrown away. The steam exhausted by the air-pump engine is discharged into the receiver.

Feed water is taken from the city main first through National heaters in the exhaust pipe of each main engine, these heaters being situated between the low-pressure cylinders and the air pumps. From here it passes to the suction of the feed pump, the discharge from the traps on the separator drips entering this pipe and mingling with the water on the way to the pump. After leaving the pump the feed water enters a secondary heater or feed-pump heater, as it is called in these pages to distinguish from the other heaters. This heater is fed with the exhaust steam from the feed pump. It was found that this heater was large enough to condense all of the exhaust steam, and so during the test the amount of steam used by the feed pump was determined by weighing the drip from the steam side of the heater.

After leaving the heater the water passes through a Green economizer rated at 2,000 H. P. before entering the boiler.

ARRANGEMENTS MADE FOR TESTING AND METHODS USED.

The pipe ordinarily supplying the feed water from the city main was broken and the water weighed in four large barrels. From these it was discharged as required into two reserve barrels, which delivered through a wrought iron pipe to the National heaters in the exhaust pipes. These barrels were supported on a platform in the engine room, the platform being high enough above the floor to give a head of five feet of water in the reserve barrels above the entrance to the heaters in the exhaust pipes.

Temperatures of feed water were taken at such places as to enable us to note the gain due to different heaters and in different sections of the economizer.

The drips from the working sides of the receivers were caught and weighed, as was also the drip from the pump heater, this latter quantity being the steam used by the feed pump.

The drips from the two separators were caught in two calibrated steel cylinders, 18″ in diameter and 4′–6″ high, having gauge glasses on the sides. Whenever these filled the reading of the upper level was taken and the discharge valve opened, a record being kept of the time this valve was open, so that allowance could be made for

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NOTE. — Quite a full description of the plant together with drawings of the engines, boilers, and stack, can be found in Vol. xii, No. 3, of Street Railway Journal.

the drip lost while discharging. As soon as the valve was closed the lower level was taken. The drips were discharged into the suction pipe of the feed pump. Owing to the fact that this hot water was liable to make the pump race, it was necessary to stop the feed pump whenever the drips were blown out. The water then backed up into the reserve barrels.

Counters were attached to both main engines and both air pumps.

Indicator cards were taken from each engine and air pump every twenty minutes. The cards were taken on the two engines alternately, the times being ten minutes apart. Crosby indicators were used on Engine No. 1 and Air Pump No. 1, and Thompson indicators on Engine and Air Pump No. 2.

The indicator rigs used on the main engines were the common "lazy tongs" pantograph, a separate set being used for each cylinder. The air-pump indicators were run by a cord attached to an eccentric pin in the end of each pump shaft.

The test was started with clean fires and everything running. The condition of the fires in Boilers No. 2 and No. 3 was noted, as were also the levels in the gauge glasses. At the closing of the test the fires were clean and were brought as nearly as possible to the condition at starting. Levels in the gauge glasses were also made right.

Samples of steam were taken by throttling calorimeters placed close to the discharge outlet of each boiler.

The temperature of the steam was taken instead of the pressure. By using long thermometer cups the temperatures could be depended upon to $\frac{5}{10}$° C., while it would be impossible to rely upon a gauge within one pound.

A machine ammeter of the Weston shunt type and a General Electric Wattmeter were connected with each machine, and were mounted on the switchboard.

A station ammeter of same type upon the switchboard measured the total current supplied by the station.

A Weston voltmeter, also mounted on the switchboard, was arranged to be connected to either machine or the main bus bar.

These instruments constitute a part of the regular equipment of the station. In addition a Weston shunt ammeter was connected to No. 1 machine, and a portable Weston voltmeter to give main voltage.

The shunt field circuits of both machines were opened and Weston ammeters inserted to indicate the field current.

The equalizer circuit between the machines was opened and a shunt ammeter, calibrated to read in either direction, was connected to show the direction and quantity of current flowing between the two machines.

The shunt field circuit does not pass through the other instruments.

All station instruments were calibrated by the General Electric Company three weeks before the test. These instruments were not recalibrated at the Institute.

The constant given by the makers for the Wattmeter is 300.

REMARKS.

At 10.05 P.M. Thursday the joint in the feed pipe at bottom of feed-pump heater blew out. The valves were immediately changed so as to cut this heater out. There was an amount of weighed water lost equal to the contents of the heater. This amount was determined after the test and allowance made for the same. The exhaust from the feed pump was, of course, turned outboard.

The joint was packed over, and at 11.25 the feed was turned through the heater again, and the exhaust steam was turned in at 11.27.

At 12.50 A.M. Friday part of the load on Engine No. 1 was transferred to Engine No. 2, leaving No. 1 light, as the commutator had been sparking badly for about two hours.

At 7.30 A.M. water backed up and ran over reserve barrels while blowing down separator-drip reservoir, and about 100 pounds of water were lost.

Barrel for condensed steam from feed pump ran over about 2.40 P.M. Friday. About 25 pounds of water were lost.

Water backed up again in reserve barrels at about 4 P.M. Friday. Loss of about 75 pounds.

On Friday evening, on account of the bad sparking of the commutator on No. 1 Dynamo, it was deemed advisable to shut the engine down and smooth up the commutator, especially as at this time the engines were running light. Accordingly, No. 2 Boiler was disconnected from the battery at 9.51 P.M. and used for No. 1 Engine and pump only. No. 3 Boiler now supplied the steam for No. 2 Engine and air pump and the feed pump, No. 2 taking about twice its former load.

The level in No. 2 Boiler was run up about $7\frac{1}{2}''$ above the center of the drums before cutting out. No water was put into this boiler until 2.17 A.M. Saturday, at which time the level had dropped, due to the blowing of the safety valves, to $\frac{1}{4}''$ below the center of the boiler. 11,936 pounds of water were now put in. While raising the level the feed valve to No. 3 Boiler was closed and record kept of the weight of water pumped into No. 2, and also of the steam used by feed pump while doing this.

At 4.20 A.M. Saturday the boiler was put into the battery again. The water level at this time was $6\frac{3}{4}''$ above the center of the drums.

The amount of water used by this boiler while shut out is equal to the amount put in plus the amount needed to bring the water level back to the level at the time of cutting out. This latter amount was estimated to be about 800 pounds, giving a total of 12,756 pounds.

The amount of coal used by this boiler while cut out was also recorded, but, inasmuch as this opportunity was taken to give the fires a thorough cleaning, it was deemed fairer to figure the amount of coal required from the water put in and the rate of evaporation as determined from the entire test.

The amount of coal and water used by the boiler while cut out is deducted from the amount required by the plant, account, of course, being taken of the time the engine was not working.

Engine No. 1 was slowed down at 9.53 P.M. Friday. At 10.11 it was shut down entirely, and started again at 10.22 and run slowly until 4 A.M., while the commutator was being sandpapered. It was then stopped to clean the commutator and adjust the brushes. At 5.03 the engine was started again and the load thrown onto the dynamo at 5.10.

While the engine was slowed down the safety valves on No. 2 Boiler were blowing for a considerable time.

At 2 A.M. Saturday, while Boiler No. 2 was cut out, the pressure in No. 3 dropped to 95 pounds, due to No. 2 Engine working beyond the capacity of the boiler, the fireman not having had a chance to clean fires before the load was thrown on. The central station, which had been shut down, then started up and took part of the load, and at 2.15 the pressure was back to 160 pounds.

STATIONS FOR TEST MAY 7, 8, 9, 1896, CHARLESTOWN POWER STATION, WEST END RAILROAD.

(1) Coal for Boilers No. 2 and No. 3. Barometer. Outside air. Temperature of fire room. Draught at base of stack. Temperature of feed water entering economizer.

(2) Feed water thermometers, entering Boilers No. 2 and No. 3. Temperature of feed water leaving economizer. Temperature at thermometers Nos. 4, 3, 2, 1 on economizer. Temperature of gases leaving economizer.

(3) Temperatures of steam, Boilers Nos. 2 and 3. Temperature of hot gases. Draught pressure and both calorimeters noting time calorimeters were in use.

(4) (5) Weigh water for boilers (four barrels each of 1,200 pounds capacity).

(6) Drip from Separator No. 1. Time and gong every ten minutes. Temperature of feed at pump. Temperature of feed leaving pump heater. Ring two sets of bells, alternating every ten minutes, thus, ... — . . — . ; ten minutes later, . . . — . . — . , etc.

(7) Drip from separator on No. 2 Engine. Counter on No. 2 Air Pump. Temperature of hot and cold condensing water of both pumps. Temperature of exhaust steam.

(8) Weight of drip from receivers on Engines No. 1 and No. 2. Also weight of steam from feed-pump heater. Temperature of feed water leaving heaters in exhaust pipe of Engines No. 1 and No. 2.

(9) Counter on No. 1 Air Pump. Cards on No. 1 and No. 2 Air Pumps. Planimeter.

(10) Temperature of cold water in reserve barrels. Pressure in receivers and vacuum in condensers of Engines No. 1 and No. 2. Measure length of cards, etc.

(11) (12) (13) Counter. Cards. Planimeter. Measure cards, etc., for both engines.

(14) General log. (Complete record of all observations.)

(15) Current Dynamo No. 1 (Main & Field) every ten minutes. Assists in work on cards.

(16) Current Dynamo No. 2 (Main & Field) every ten minutes. Assists in work on cards.

(17) Voltmeter every ten minutes. Works on cards.

(18) Work on cards, all engines. Planimeter, length, and per cent. cut-off.

DATA AND RESULTS OF TEST ON WEST END POWER STATION AT CHARLESTOWN.

Areas and Weights.

	Boiler No. 2.	Boiler No. 3.
Total heating surface	5,372 sq. ft.	5,372 sq. ft.
Total grate surface	88.1 sq. ft.	88.1 sq. ft.
Total coal fired	48,345 lbs.	57,190 lbs.
Coal drawn from grate	200 lbs.	60 lbs.
Total coal burned	48,145 lbs.	57,130 lbs.
Weight of ashes, clinkers, etc.	4,195 lbs.	5,000 lbs.
Total combustible	43,950 lbs.	52,130 lbs.
Estimated weight of water in coal		2.7%
Total coal (including moisture)		105,275 lbs.
Coal used by Boiler No. 2 while shut off (figured from water put in and the rate of evaporation). (See remarks.)		1,345 lbs.
Total coal during test		103,390 lbs.
Total ash during test		9,080 lbs.
Total combustible during test		94,850 lbs.
Total water weighed in barrels (50 hours)		957,995 lbs.
Returns from separator drip cans (50 hours)		Engine No. 1, 20,310 lbs. Engine No. 2, 21,590 lbs.
Total water put into boilers by feed pump (50 hours)		999,895 lbs.
Weight of water put into Boiler No. 2 while shut off, including allowance made for difference of level when boiler was connected from that at shutting off		12,755 lbs.
Steam used by feed pump feeding No. 2 while shut off		285 lbs.
Total water during test		987,140 lbs.

Weights.

Drip from working side of receiver per hour	Engine No. 1, 362.4 lbs. Engine No. 2, 229.3 lbs.
Steam used by feed pump	32,398 lbs.
Steam used by both calorimeters	2,646 lbs.
Quality of steam at boilers; mean of calorimeter tests	Boiler No. 2, .990 lbs. Boiler No. 3, .990 lbs.
Average	.990 lbs.
Steam required by plant, both engines running, Engine No. 1 running 42.72 hours, and Engine No. 2 running 50 hours	984,494 lbs.
Coal for plant (deducting coal required for steam used by calorimeter, 278 lbs.),	103,652 lbs.
Coal per hour for plant, figured by dividing above by average time both engines were running $= \frac{50 + 42.72}{2} = 46.36$	2,236 lbs.

Temperatures.

Temperature boiler room	81.6° F.
Temperature outside air	57.9° F.
Temperature steam at boiler	No. 2, 179.4° C. No. 3, 177.2° C.
Temperature cold feed water at barrels	16.5° C.
Temperature leaving heaters in exhaust pipe	No. 1, 60.1° C. No. 2, 62.4° C.
Temperature entering feed pump	59.9° C.
Temperature leaving heater supplied with feed pump steam	77.5° C.
Temperature entering economizer	75.9° C.
Temperature after passing through 30 tubes of economizer	73.1° C.[1]
Temperature after passing through 150 tubes of economizer	77.7° C.
Temperature after passing through 270 tubes of economizer	79.9° C.

[1] Drop in temperature due to leakage of cold air.

Temperature after passing through 410 tubes of economizer	87.1° C.
Temperature leaving economizer (560 tubes)	91.6° C.
Temperature entering boilers	No. 2, 94.0° C. No. 3, 97.8° C.
Temperature exhaust steam from engines close to condensers	No. 1, 137.6° F.
Temperature injection water entering condenser	No. 1, 12.5° C. No. 2, 13.0° C.
Temperature injection water leaving condenser	No. 1, 25.4° C. No. 2, 30.4° C.
Temperature drip from separator	No. 1, 171.1° C. No. 2, 142.4° C.
Temperature hot flue gases at back of boiler	213.7° C.
Temperature flue gases leaving economizer	152.2° C.

Pressures and Time.

Barometer	30.305
Vacuum in condensers	No. 1, 12.04 lbs. No. 2, 12.26 lbs.
Pressure in receivers	No. 1, 8.3 lbs. No. 2, 7.9 lbs.
Draught at back of boilers (inches of water)	Average, .2997 Maximum, .602
Draught at base of stack (inches of water)	Average, .3727. Maximum, .656
Time starting test	Thursday, 3.30 P.M.
Time stopping No. 1 Engine	Friday, 9.53 P.M.
Time starting No. 1 Engine (loaded)	Saturday, 5.10 A.M.
Time cutting No. 2 Boiler out	Friday, 9.51 P.M.
Time putting No. 2 Boiler in again	Saturday, 4 20 A.M.
Time ending test	Saturday, 5.30 P.M.
Total time Engine No. 1 was working	42 hrs. 43 mins.
Total time Engine No. 2 was working	50 hrs.
Total time Boiler No. 2 was working	43 hrs. 31 mins.
Total time Boiler No. 3 was working	50 hrs.
Total time feed-pump heater was cut out	1 hr. 20 mins.

Revolutions.

Total revolutions No. 1 Air Pump,	42.67 hours			156,598	
Total revolutions No. 2 Air Pump,	49.33 hours			178,451	
Average M. E. P. Pump No. 1		H. E.,	17.46	C. E. 30.25	
Average M. E. P. Pump No. 2		H. E,	18.94	C. E. 24.56	
H. P. Pump No. 1		H. E.,	4.66	C. E. 8.17	Total, 12.83
H. P. Pump No. 2, H. E.			5.22	C. E. 6.54	Total, 11.76

Total revolutions Engine No. 1, First,	9.67 hours	50,533	
Second,	12.00 hours	63,358	
Third,	8.67 hours	44,903	
Fourth,	7.00 hours	Not running.	
Last,	12.33 hours	64,128	
Total time	42.67	222,922 total revolutions.	

Total revolutions Engine No. 2, First,	9.67 hours	50,501	
Second	12.00 hours	62,882	
Third,	8.67 hours	44,586	
Fourth,	7.00 hours	35,831	
Last,	12.33 hours	64,302	
Total time	49.67	258,102 total revolutions.	

M. E. P. AND PER CENT. OF CUT-OFF.

M. E. P. Engine No. 1.

Time.	High.		Low.	
	H. E.	C. E.	H. E.	C. E.
9.67	32.18	27.75	9.92	7.72
12.00	17.62	14.64	7.38	5.79
8.67	34.93	26.55	9.94	8.44
7.00 not running.	.....	.....	....	....
12.33	30.98	23.92	9.21	7.19
Average M.E.P. per hour entire run	28.17	23.59	9.00	7.18

M. E. P. Engine No. 2.

Time.	High.		Low.	
	H. E.	C. E.	H. E.	C. E.
9.67	29.43	16 04	9.35	9.84
12.00	23.71	9.84	8.29	8.78
8.67	37.75	23.99	10.29	10.61
7.00	35.80	22.89	10.58	10.83
12.33	30.87	16.16	8.77	9.04
Av. M.E.P. for entire test,	30.74	16.80	9.28	9.64

Per Cent. of Cut-off Engine No. 1.

Time.	High.		Low.	
	H. E.	C. E.	H. E.	C. E.
9.67	15.21	11.22	33.84	21.07
12.00	7.65	6.25	30.63	20.78
8.67	18.66	13.45	36.58	23.73
7.00	.....	....	.....	.....
12.33	16.70	11.52	33.42	21.40
Average entire test . .	14.13	10.35	33.74	21.61

M. E. P. AND PER CENT. OF CUT-OFF. — *Continued.*

Per Cent. of Cut-off Engine No. 2.

Time.	High.		Low.	
	H. E.	C. E.	H. E.	C. E.
9.67	18.82	9.38	29.51	27.35
12.00	15.84	7.07	26.36	25.21
8.67	23.17	13.59	36.33	31.82
7.00	24.85	15.75	37.64	37.80
12.33	17.62	8.82	30.01	28.62
Av. entire test . . .	19.39	10.35	31.30	29.36

ELECTRICAL DATA.

Dynamo No. 1.			Dynamo No. 2.					
Time.	Main current.	Field current.	Time.	Main current.	Field current.	Time.	Total current.	Voltage.
9.67	768.4	7.715	9.67	864.8	6.756	9.67	1,633.2	566.02
12.00	559.4	7.559	12.00	696.5	6.949	12.00	1,255.9	561.05
8.67	870.8	8.168	8.67	934.6	7.306	8 67	1,805.4	565.33
7.00	....	....	7.00	949.0	6.782	7.00	949.0	566.98
12.33	745.9	8.056	12.33	790.3	7.267	12.33	1,536.2	570.11
Av. entire test . .	724.4	7.861	Av. entire test . .	732.2	7.060	Av. entire test . .	1,456.6	565.80

Wattmeter Readings.

Time.	Dynamo No. 1.		Dynamo No. 2.	
	Reading.	Difference.	Reading.	Difference.
Thursday, 3.30 P.M. . . .	2,845,500		3,580,290	
Friday, 12.30 A.M. . . .	2,983,320	137,820	3,729,120	148,830
Friday, 12.30 P.M. . . .	3,114,180	130,860	3,890,720	161,600
Friday, 9.30 P.M. . . .	3,257,120	142,940	4,058,800	168,080
	Shut down till 5.10.			
Saturday, 5.30 A.M. . . .	3,271,950	14,830	4,201,700	142,900
Saturday, 5.30 P.M. . . .	3,446,080	174,130	4,389,830	188,130
		600,580		809,540

SIZES OF ENGINES.

Sizes of Engines Nos. 1 and 2.

Diameter high.	Diameter rod.	Diameter low.	Diameter rod.	Stroke.
26″	5″	50″	6″	48″

Air Pump Engines Nos. 1 and 2.

Diameter Cylinder.	Diameter rod.	Stroke.
12″	$2\frac{3}{16}$″	16″

BOILER SIZES.

There are 21 sections in each boiler, each section containing

12 tubes, 4″ outside diameter, 18′ 6″ long.
1 tube, $4\frac{1}{2}$″ outside diameter, 5′ 8″ long.
2 tubes, $4\frac{1}{2}$″ outside diameter, 0′ 10″ long.
1 tube, $4\frac{1}{2}$″ outside diameter, 0′ 10″ long.
1 face of front and rear headers; estimated total for the 21 sections, 21.99 square feet.
Deduct for smoke consuming tile 21 tubes, $\frac{1}{3}$ circumference covered with 3 tiles, each 18″ long, and 21 tubes with 2 tiles, each 18″ long.
3 drums bricked at center of diameter, 42″ inside diameter, $\frac{7}{16}$″ plate.
21 feet of length of drum exposed to fire.
Smoke connection, 72″ x 42″.
Grate, 7′ x 12′ 7″.
Air space, 40% of grate surface.
Smoke connection, 21 square feet.
Grate surface, 88.08 square feet.
Heating surface, 5,344 square feet.

RESULTS.

Water apparently evaporated per pound of coal	9.498 lbs.
Equivalent from and at 212° F. per pound of coal, not including economizer	9.91 lbs.
Equivalent from and at 212° F. per pound of coal, including economizer	10.27 lbs.
Equivalent from and at 212° F. per pound of combustible, including economizer	11.25 lbs.
Coal per square foot of grate per hour, No. 2	12.57 lbs.
Coal per square foot of grate per hour, No. 3	12.97 lbs.
H. P. No. 1 Air Pump	12.83
H. P. No. 2 Air Pump	11.76

H. P. No. 1 Engine.

	1st. 9.67 hours.	2d. 12 hours.	3d. 8.67 hours.	4th. 7 hours.	5th. 12.33 hours.
H. H.	180.43	99.78	194.11	.....	172.78
H. C.	149.84	79.85	142.09	.....	128.47
Total	330.27	179.63	336.20	.....	301.25
L. H.	205.70	154.56	204.28	.....	189.95
L. C.	157.77	119.52	170.96	.....	146.16
Total	363.47	274.08	375.24	.....	336.11
Total H. and L.	693.74	453.71	711.44	.....	637.36

Average H. P. No. 1 Engine 618.34

H. P. No. 2 Engine.

	1st. 9.67 hours.	2d. 12 hours.	3d. 8.67 hours.	4th. 7 hours.	5th. 12.33 hours.
H. H.	164.91	133.26	208.30	196.55	172 63
H. C.	86.55	53.26	127.48	121.03	87.03
Total	251.46	186.52	335.78	317.58	259.66
L. H.	193.76	172.32	209.98	214.82	181.37
L. C.	200.97	179.87	213.40	216.73	184.26
Total	394.73	352.19	423.38	431.55	365.63
Total H. and L.	646.19	538.71	759.16	749.13	625.29

Average H. P. No. 2 Engine 648.65

RESULTS. — *Continued.*

No. 1 Engine.

	1st. 9.67 hours.	2d. 12 hours.	3d. 8.67 hours.	4th. 7 hours.	5th. 12.33 hours.
Kilowatts	434.93	313.85	492.29	.....	425.24
H. P. output	583.02	420.71	659.91	.....	570.04

Average kilowatts, 50 hours (calculated)	409.87
Average H. P. output, 50 hours	549.42

No. 2 Engine.

	1st. 9.67 hours.	2d. 12 hours.	3d. 8.67 hours.	4th. 7 hours.	5th. 12.33 hours.
Kilowatts	489.49	390.77	528.35	538.06	450.56
H. P. output	656.16	523.82	708.25	721.26	603.97

Average kilowatts, 50 hours (calculated)	414.28
Average H. P. output, 50 hours	555.33
Coal per steam H. P. per hour of main engines while engines were running	1.76 lbs.
Coal for plant per H. P. output per hour	2.02 lbs.
Coal for plant per kilowatt per hour	2.71 lbs.
Electrical efficiency	87.2

Boiler Tests.

The summaries given represent the results of three tests made, not primarily with the aim of determining the evaporation per pound of coal, but to get, if possible, some idea of the ratio of heating surface to grate area, and also to find the loss of draught pressure and the leakage of air at different parts of the setting.

The boiler tested is set in battery with another boiler of the same size, there being a 20″ wall between the two.

The boiler is 60″ in diameter, 16 feet long, with eighty-four 3″ tubes 16 feet long. It rates at 100 horse power (A. S. M. E. rating). Built by the Roberts Iron Works Company, of Cambridgeport, Massachusetts.

The total heating surface, taking one half the shell and the inside surface of the tubes, is 1,113 square feet.

The grate area is 25.9 square feet. The grate is 24 inches from boiler.

The bridge wall is straight across the top, and 8 inches below the bottom of the boiler.

During the first test (Nos. 146–148) the boiler tested was run at a maximum rate, fires in the other boiler being banked.

During the second test (Nos. 149–151) 38 tubes were plugged, reducing the heating surface from 1,113 to 670.6 square feet. The boiler was run so as to keep the evaporation per square foot of heating surface the same as in the first test.

The same method was followed in the third test, 52 tubes being plugged and the heating surface reduced to 507.5 square feet.

During the second and third tests Boiler No. 4 was run at a moderate rate, and there may have been some heat carried to No. 5 Boiler through the middle wall of the setting. Before the test the brickwork of the setting was pointed up. The brickwork was not whitewashed. The tubes were plugged with iron caps at both ends.

Samples of gas and draught pressures were taken at different parts of the setting, porcelain tubes having been built into the setting for this purpose. These tubes were located over the grate, in the ash pit, over the bridge wall, halfway from bridge wall to the back of the boiler, at the back end of the boiler, and in the uptake.

The gases from both boilers were discharged into a wrought iron stack (unlined), 3 feet diameter and 100 feet tall. An iron ladder and four stagings were built on the wall of the building near the stack, and observations of temperature and draught pressure were taken at these four points in addition to the others.

These readings are quite interesting, as they give some idea of the loss of draught pressure with loss of temperature, and also the amount of cooling of the gases.

The accompanying photograph (Fig. 1), taken during the test, shows the ladder and the protection given the stack by surrounding buildings.

FIG. 1. THE SMOKE-STACK AND LANDINGS.

SUMMARY OF A 24-HOUR BOILER TEST.

Date, January 13, 1896, 8 A. M., to January 14, 8 A. M. Nos. 146–148.

Time.	Pressures.		Temperatures. °C.					Weights.		Results of calorimeter experiments.	Remarks.
	Barometer. (Lbs. per sq. in.)	Steam gauge.	Outside air.	Flue.	Feed before.	Feed after.	Temperature fire room.	Lbs. of water. (Boiler No. 5.)	Lbs. of fuel. (Boiler No. 5.)		
Jan. 13. 8 to 4.	14.74	63.5	1.4	199	8.2	27.6	....	35,582	4,640	.993	Ash and clinker. 410
Jan. 13. 4 to 12.	14.77	69.5	— .9	206	6.4	28.1	18.1	30,848	3,900	.994	566
Jan. 14. 12 to 8.	14.76	73.5	—3.4	218	7.8	35.7	24.2	28,423	3,768	.994	438
Total,		206.5	—2.9	623	22.4	91.4		94,853	12,308		1,414
Average,	14.76	68.8	—.97	208	7.5	30.5				.994	

		Boiler No. 5.
1.	Description of boiler: Horizontal multitubular.	
2.	Grate surface, No. 5, 60¾ in. by 61½ in. Area, feet	25.9
3.	Water-heating surface, feet	1,113.3
4.	Ratio of water-heating surface to grate surface	42.9
5.	Pounds coal fired, including coal equivalent of wood	12,308
6.	Unburned fuel	0
7.	Coal burned, including coal equivalent of wood	12,308
8.	Average coal burned for 15 minutes	128.21
9.	Total refuse from coal	1,414
10.	Total combustible	10,894
11.	Average combustible for 15 minutes	113.48
12.	Average pounds of air for — minutes	———
13.	Air per pound of coal	———
14.	Air per pound of combustible	———
15.	Quality of steam, saturated steam taken as unity	.994
16.	Total water pumped into boiler and apparently evaporated	94,853
17.	Water apparently evaporated per pound of coal	7.71
18.	Water actually evaporated, corrected for quality of steam	94,284
19.	Equivalent water evaporated into dry steam, from and at 212° F.	113,794
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	9.24
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	10.44
22.	Coal burned per square foot of grate surface per hour	19.8
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	4.26

Analysis of Coal.	Analysis of Ash.
C, 82.41%	C, 23.7%
H, 1.80%	H, 0.2%
H_2O, 1.87%	Ash, 75.0%
Ash, 9.46%	

Entire heating surface. No tubes plugged.

TEMPERATURE. °CENT.

Date, January 13–14, 1896. Nos. 146–148.

Time.	Flue.	Stack. 1st landing.	Stack. 2d landing.	Stack. 3d landing.	Stack. 4th landing.	Time.	Flue.	Time.	Flue.
8.00	200	....	....	....	....	4.30	215	2.00	230
8.15	207	....	....	....	....	4.45	200	2.15	236
8.30	191	....	....	....	....	5.00	210	2.30	230
8.45	180	....	....	....	....	5.15	202	2.45	232
9.00	194	....	....	....	....	5.30	220	3.00	213
9.15	185	....	....	....	....	5.45	222	3.15	202
9.30	172	....	....	....	....	6.00	215	3.30	225
9.45	190	....	....	....	....	6.15	230	3.45	227
10.00	190	....	....	....	....	6.30	225	4.00	232
10.15	192	....	....	....	....	6.45	210	4.15	211
10.30	185	....	....	....	....	7.00	212	4.30	202
10.45	190	....	....	....	....	7.15	228	4.45	224
11.00	206	....	....	....	....	7.30	219	5.00	234
11.15	192	....	....	....	....	7.45	196	5.15	222
11.30	205	....	....	....	....	8.00	204	5.30	....
11.45	195	....	....	....	....	8.15	195	5.45	218
12.00	206	200	193	182	157	8.30	205	6.00	....
12.10	....	190	188	185	162	8.45	202	6.15	....
12.15	198	....	....	....	....	9.00	197	6.30	226
12.20	....	198	189	188	168	9.15	207	6.45	191
12.30	212	202	195	187	174	9.30	205	7.00	206
12.40	....	197	187	187	173	9.45	217	7.15	230
12.45	199	....	....	....	....	10.00	205	7.30	239
12.50	....	198	189	186	172	10.15	198	7.45	220
1.00	206	202	194	179	174	10.30	186	8.00	210
1.15	195	....	....	....	....	10.45	204	....	....
1.30	201	....	....	....	....	11.00	213	....	....
1.45	214	....	....	....	....	11.15	203	....	....
2.00	221	....	....	....	....	11.30	156	....	....
2.15	216	....	....	....	....	11.45	176	....	....
2.30	197	....	....	....	....	12.00	208	....	....
2.45	206	....	....	....	....	12.15	210	....	....
3.00	192	....	....	....	....	12.30	220	....	....
3.15	208	....	....	....	....	12.45	209	....	....
3.30	214	....	....	....	....	1.00	193	....	....
3.45	211	....	....	....	....	1.15	215	....	....
4.00	210	....	....	....	....	1.30	210	....	....
4.15	209	....	....	....	....	1.45	....	....	....

GAS ANALYSIS.

Date, January 13–14, 1896. Nos. 146–148.

Time.	Over Grate.				Over Bridge Wall.				Back of Boiler.				Flue.			
	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.
8.00	....	...	....	....	....	...	....	....	....	....	...	....	....	....	...	....
9.00	....	...	....	....	....	...	....	....	....	....	...	....	....	....	...	....
10.00	7.2	0.4	15.4	77.0	9.0	0.0	16.4	74.6	....	....	...	....	13.0	5.4	0.4	81.2
11.00	4.8	0.2	19.8	75.2	8.0	0.4	19.8	71.8	18.2	0.4	3.2	78.2	14.6	5.6	0.0	79.8
12.00	....	...	....	....	....	...	....	....	....	....	...	....	....	....	...	....
1.00	5.8	0.0	17.9	76.3	8.8	0.0	15.0	76.2	7.6	11.6	0.4	80.4	12.0	8.2	0.0	79.8
2.00	15.0	0.0	7.4	77.6	12.0	0.6	12.4	75.0	10.0	9.6	0.4	80.0	12.6	8.2	0.2	79.0
3.00	9.0	0.2	15.6	75.2	13.8	0.4	9.6	76.2	14.4	3.6	0.0	82.0	12.0	8.4	0.0	79.6
4.00	....	...	....	....	13.3	0.2	7.7	78.8	16.1	3.5	0.5	79.9	10.6	8.4	...	....
5.00	....	...	....	....	12.0	0.4	5.5	82.1	13.5	4.8	1.1	80.6	11.6	9.6	0.2	78.6
6.00	....	...	....	....	11.1	0.6	10.5	77.8	14.3	1.5	1.1	83.1	12.4	7.1	0.0	80.5
7.00	....	...	....	....	4.1	9.9	7.9	78.1	14.2	1.7	0.2	83.9	11.3	8.6	0.0	80.1
8.00	....	...	....	....	10.1	7.5	2.8	79.6	9.0	9.6	0.0	81.4	9.6	10.6	0.0	79.8
9.00	....	...	....	....	14.0	2.0	5.0	79.0	14.3	5.0	0.2	80.5	10.4	9.2	0 0	80.2
10.00	....	...	....	....	8.6	9.5	1.5	80.4	10.5	8.8	0.1	80.6	8.3	11.9	0.0	79.8
11.00	....	...	....	....	10.1	4.2	5.7	80.0	12.1	7.9	0.0	80.0	8.8	12.0	0.0	79.0
12.00	....	...	....	....	11.8	0.8	9.2	78.2	6.4	14.2	0.0	79.4	10.1	9.4	0.0	80.5
1.00	....	...	....	....	13.0	3.4	3.9	79.7	11.0	9.4	0.1	79.5	10.4	8.8	0.0	80.8
2.00	....	...	....	....	9.4	0.6	12.3	77.7	13.6	5.2	0.0	81.2	10.0	8.2	0.0	82.8
3.00	....	...	....	....	....	...	....	....	9.2	9.4	0.0	81.4	11.8	8.2	0.0	80.0
4.00	....	...	....	....	14.8	0.6	2.4	82.2	10.6	9.2	0.0	81.2	8.2	12.8	0.0	79.0
5.00	....	...	....	....	11.4	0.8	9.8	78.0	12.6	7.7	0.0	79.7	10.0	10.2	0.0	79.8
6.00	....	...	....	....	17.0	0.0	2.1	80.9	6.0	14.6	0.0	79.4	10.7	9.6	0.0	79.7
7.00	....	...	....	....	10.0	1.0	8.0	81.0	11.0	9.7	0.0	79.3	9.3	11.0	0.0	79.7
8.00	....	...	....	....	9.5	1.5	10.0	79.0	10.6	9.0	0.0	80.4	10.4	5.6	0.0	84.0

DRAUGHT PRESSURE. Inches of Water.

Date, January 13–14, 1896. Nos. 146–148.

Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.	Stack.			
						1st landing.	2d landing.	3d landing.	4th landing.
8.00	.236	.382	.358	.284	.529	24′ 3″ above center of flue.	51 feet above grate.	68 feet above grate.	85 feet above grate.
8.10					.515				
8.20					.542				
8.30	.204	.362	.352	.284	.538				
8.40					.503				
8.50					.511				
9.00	.232	.356	.390	.310	.522				
9.10					.520				
9.20					.491				
9.30	.256	.402	.424	.372	.518				
9.40					.528				
9.50					.544				
10.00	.252	.388	.434	.380	.527				
10.10					.526				
10.20					.552				
10.30	.164	.456	.446	.400	.526				
10.40					.535				
10.50					.558				
11.00	.170	.334	.330	.374	.439				
11.10					.543				
11.20					.565				
11.30	.218	.372	.374	.334	.542				
11.40					.563				
11.50					.562				
12.00	....	....	....	....	.546	.440		.168	.086
12.10					.554	.414	.332	.188	.116
12.20					.560	.428	.312	.168	.106
12.30	....	....	....	....	.572	.428	.312	.188	.104
12.40					.545	.434	.314	.186	.122
12.50					.556	.436	.328	.196	.088
1.00	....	....	....	....	.557	.436	.334	.216	.110

DRAUGHT PRESSURE. INCHES OF WATER. — *Continued.*

Date, January 13–14, 1896. Nos. 146–148.

Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.	Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.
1.10					.543	10.40					.527
1.20					....	10.50					.438
1.30	.240	.382	.410	.354	.560	11.00	.176	.336	....	.246	.510
1.40					.553	11.10					.463
1.50					.553	11.20					.365
2.00	.206	.322	.424	.288	.547	11.30	.186	.396	....	.326	.369
2.10					.569	11.40					.447
2.20					....	11.50					....
2.30	.170	.328	.372	.258	.443	12.00	.206	.356	....	.332	.688
2.40					.553	12.10					.558
2.50					....	12.20					.625
3.00	.228	.362	.364	.330	.546	12.30	.178	.398	....	.254	.523
3.10					.560	12.40					.495
3.20					.570	12.50					....
3.30	.258	.364	.424	.338	.560	1.00	.226	.388	....	.336	.638
3.40					.570	1.10					.428
3.50					.576	1.20					.420
4.00	.228	.348	.374	.244	.583	1.30	.114	.178	....	.146	....
4.10					.578	1.40					....
4.20					.588	1.50					.610
4.30	.236	.338	....	.278	.580	2.00	.248	.374	....	.342	.622
4.40					.588	2.10					.620
4.50					.588	2.20					.638
5.00	.240	.402	....	.348	.589	2.30	.190	.342	....	.300	.674
5.10					.581	2.40					.674
5.20					.604	2.50					....
5.30	.214	.322	....	.336	.577	3.00	.188	.344	....	.286	....
5.40					.589	3.10					.480
5.50					.589	3.20					.600
6.00	.228	.392	....	.366	.597	3.30	.308	.340	.284	.334	.616
6.10					.598	3.40					.618
6.20					.596	3.50					.614
6.30	.198	.260	....	.322	.597	4.00	.160	.238	.244	.202	.574
6.40					.457	4.10					.606
6.50					.599	4.20					.580
7.00	.214	.380	....	.354	.592	4.30	.168	.156	.234	.228	.618
7.10					.582	4.40					.516
7.20					.562	4.50					.570
7.30	.162	.314	....	.334	.605	5.00	.176	.314	.328	.262	.570
7.40					.573	5.10					.552
7.50					.585	5.20					.580
8.00	.220	.346	....	.356	.572	5.30	.176	.142	.232	.364	.594
8.10					.571	5.40					.608
8.20					.588	5.50					.616
8.30	.206	.368	....	.326	.590	6.00	.228	.324	.314	.294	.614
8.40					.560	6.10					.538
8.50					.562	6.20					....
9.00	.126	.394	....	.320	.513	6.30	.218	.136	.146	.206	.594
9.10					.516	6.40					....
9.20					.565	6.50					.564
9.30	.154	.366	....	.174	.405	7.00	.238	.340	.366	.340	.600
9.40					.408	7.10					.600
9.50					.464	7.20					.602
10.00	.168	.340	....	.206	.460	7.30	.236	.010	.380	.200	.604
10.10					.463	7.40					.632
10.20					.242	7.50					.724
10.30	.204	.342	....	.164	.241	8.00	.192	.018	.324	.186	....

SUMMARY OF A 22¾-HOUR BOILER TEST.

Date, January 14, 1896, 9.15 A.M., to January 15, 8 A.M. Nos. 149–151.

Time.	Pressures.		Temperatures. °C.					Weights.			Results of calorimeter experiments.	Remarks.
	Barometer. (Lbs. per sq. in.)	Steam gauge.	Outside air.	Flue.	Feed before.	Feed after.	Temperature boiler room.	Lbs. of water. (Boiler No. 5.)	Lbs. of fuel. (Boiler No. 5.)	Average lbs. of air. (Boiler No 5, for 15 minutes.)		
Jan. 14. 9.15 to 4.	14.76	72.9	4.5	193	6.8	27.0	26.0	17,791	2,300	1,594	.995	Ashes and clinkers. 388
Jan. 14. 4 to 12.	14.80	74.3	— .4	208	7.4	30.4	27.3	23,905	3,150	1,396	.994	611
Jan. 15. 12 to 8.	14.85	76.8	—2.7	207	8.1	27.2	23.5	21,935	3,150	1,420	.993	438
Total,		224.0	1.4	608	22.3	84.6	76.8	63,631	8,600	4,410	.994	1,437
Average,	14.80	74.7	+.5	203	7.4	28.2	25.6			1,470		

		Boiler No. 5.
1.	Description of boiler: Horizontal multitubular.	
2.	Grate surface, No. 5, 60⅛ in. by 61½ in. Area, feet	25.9
3.	Water-heating surface, feet	670.6
4.	Ratio of water-heating surface to grate surface	25.9
5.	Pounds coal fired, including coal equivalent of wood	8,600
6.	Unburned fuel	0
7.	Coal burned, including coal equivalent of wood	8,600
8.	Average coal burned for 15 minutes	94.51
9.	Total refuse from coal	1,437
10.	Total combustible	7,163
11.	Average combustible for 15 minutes	78.71
12.	Average pounds of air for 15 minutes	1,470
13.	Air per pound of coal	1,556
14.	Air per pound of combustible	18.7
15.	Quality of steam, saturated steam taken as unity	.994
16.	Total water pumped into boiler and apparently evaporated	63,631
17.	Water apparently evaporated per pound of coal	7.41
18.	Water actually evaporated, corrected for quality of steam	63,249
19.	Equivalent water evaporated into dry steam, from and at 212° F.	76,484
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	8.89
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	10.67
22.	Coal burned per square foot of grate surface per hour	14.6
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	5.01

Analysis of Coal.	Analysis of Ash.
C, 82.41 %	C, 23.7 %
H, 1.80 %	H, 0.2 %
H_2O, 1.87 %	Ash, 75 %
Ash, 9.46 %	

In this test 38 tubes were plugged, reducing the heating surface 442.7 square feet; the heating surface left being 670.6 square feet. This test was 22.75 hours long.

TEMPERATURE. °CENT.

Date, January 14–15, 1896. Nos. 149–151.

Time.	Flue.	Stack. 1st landing.	Stack. 2d landing.	Stack. 3d landing.	Stack. 4th landing.	Time.	Flue.	Time.	Flue.
9.15	160	....	....	....	....	5.45	214	3.15	210
9.30	193	....	....	....	....	6.00	201	3.30	213
9.45	198	....	....	....	....	6.15	215	3.45	205
10.00	197	....	....	....	....	6.30	217	4.00	175
10.15	167	....	....	....	....	6.45	216	4.15	209
10.30	168	....	....	....	....	7.00	209	4.30	211
10.45	194	....	....	....	....	7.15	211	4.45	193
11.00	200	....	....	....	....	7.30	222	5.00	211
11.15	193	....	....	....	....	7.45	215	5.15	203
11.30	180	....	....	....	....	8.00	209	5.30	214
11.45	195	....	....	....	....	8.15	216	5.45	187
12.00	200	188	182	182	173	8.30	209	6.00	212
12.10	....	198	195	185	173	8.45	180	6.15	219
12.15	190	....	....	....	....	9.00	202	6.30	215
12.20	....	196	193	188	174	9.15	212	6.45	197
12.30	202	195	193	187	174	9.30	212	7.00	192
12.40	....	190	189	187	170	9.45	194	7.15	213
12.45	205	....	....	....	....	10.00	215	7.30	228
12.50	....	194	192	186	174	10.15	222	7.45	228
1.00	205	189	187	179	168	10.30	210	8.00	218
1.10	....	187	180	176	168	10.45	193	....	....
1.15	200	....	....	....	....	11.00	166	....	....
1.30	193	....	....	....	....	11.15	200	....	....
1.45	191	....	....	....	....	11.30	203	....	....
2.00	197	....	....	....	....	11.45	214	....	....
2.15	193	....	....	....	....	12.00	225	....	....
2.30	186	....	....	....	....	12.15	220	....	....
2.45	188	....	....	....	....	12.30	210	....	....
3.00	185	....	....	....	....	12.45	185	....	....
3.15	185	....	....	....	....	1.00	205	....	....
3.30	208	....	....	....	....	1.15	213	....	....
3.45	215	....	....	....	....	1.30	211	....	....
4.00	214	....	....	....	....	1.45	191	....	....
4.15	217	....	....	....	....	2.00	206	....	....
4.30	212	....	....	....	....	2.15	210	....	....
4.45	204	....	....	....	....	2.30	208	....	....
5.00	213	....	....	....	....	2.45	185	....	....
5.15	210	....	....	....	....	3.00	204	....	....
5.30	190	....	....	....	....	....	....	....	....

GAS ANALYSIS.

Date, January 14–15, 1896. Nos. 149–151.

Time.	Over Grate.				Over Bridge Wall.				Back of Boiler.				Flue.			
	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.
9.30	13.8	0.2	5.8	80.2	14.0	5.0	0.0	81.0	8.6	11.2	0.0	80.2	8.0	11.0	0.0	81.0
10.30	12.8	0.8	0.7	85 7	5.1	14.1	0.0	80.8	8.0	11.6	0.0	80.4	5.4	13.6	0.0	81.0
11.30	12.0	5.6	0.0	82.4	5.5	14.5	0.0	80.0	7.8	10.6	0.0	81.6	6.2	13.0	0.0	80.8
1.00	....	....	...	....	....	....	..	....	....	....	....	....	....	....	....	....
2.00	10.0	10.4	0.0	79.6	6.0	15.0	0.0	79.0	6.0	13.8	0.0	80.2	7.2	12.8	0.0	80.0
3.00	9.2	0.6	8.0	82.2	5.5	14.0	1.0	79.5	17.2	8.0	0.0	80.8	7.8	11.2	0.0	81.0
4.00	19.0	8.5	5.1	67.4	18.4	1.6	0.7	79.3	3.8	17.0	0.0	79.2	10.8	9.5	0.2	79.5
5.00	17.2	10.6	8.4	63.8	13.6	7.4	0.0	79.0	8.6	12.6	0.0	78.4	....	....	....	....
6.00	12.0	7.8	0.7	79.5	11.0	9.4	6.6	82.0	5.2	14.6	0.0	80.2	0.5	20.3	0.2	79.0
7.00	13.7	6.1	0.4	79.8	15.8	0.2	3.4	80.8	13.9	4.8	0.1	82.0	11.5	7.7	0.2	79.6
8.00	17.0	2.7	0.1	80.2	15.8	1.0	1.7	81.5	10.9	7.8	0.1	81.2	10.0	10.0	0.0	80.0
9.00	12.2	5.4	0.1	82.3	15.8	0.2	0.2	83.8	9.8	9.2	0.0	81.0	9.3	10.7	0.0	80.0
10.00	11.5	5.7	1.3	81.5	17.0	3.0	0.0	80.0	7.0	13.0	0.1	79.9	9.2	10.6	0.2	80.0
11.00	5.2	14.9	0.0	79.9	12.1	7.5	0.0	80.4	7.2	12.1	0.0	80.7	6.8	13.2	0.2	79.8
12.00	11.4	7.4	0.1	81.1	14.2	6.8	2.0	77.0	8.8	12.2	0.0	80.0	....	....	....	....
1.00	17.0	0.6	1.4	81.0	17.8	3.2	0.0	79.0	4.8	16.0	0.0	79.2	....	....	....	....
2.00	16.2	2.4	0.8	80.6	14.8	1.2	0.2	83.8	9.0	11.4	0.1	79.5	....	....	....	....
3.00	13 0	1.4	5.4	81.2	16.6	2.4	0.0	81.0	11.2	8.3	0.1	80.4	....	....	....	....
4.00	13.0	2.1	3.5	81.4	13.0	6.0	0.2	80.8	9.6	9.0	0.1	81.3	....	....	....	....
5.00	8.4	0.6	10.8	80.2	15.6	0.6	1.8	82.0	12.0	7.4	0.2	80.4	....	....	....	....
6.00	10.2	0.8	10.2	78.8	18.6	0.8	0.0	80.6	11.8	8.4	0.2	79.6	....	....	....	....
7.00	12.6	0.8	4.4	82.2	11.0	0.4	0.0	88.6	14.1	4.9	0.1	80.9	....	....	....	....
8.00	13.0	9.8	1.6	75.6	2.3	16.7	0.0	81.0	9.5	9.5	0.1	80.9	....	....	....	....

DRAUGHT PRESSURE. Inches of Water.

Date, January 14–15, 1896. Nos. 149–151.

Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.	Stack.			
						1st landing.	2d landing.	3d landing.	4th landing.
9.20					.458				
9.30	.124	....	.100	.172	.498				
9.40					.480				
9.50					.472				
10.00	.120	....	.154	.148	.506				
10.10					.460				
10.20					....				
10.30	.136	....	.118	.206	.438				
10.40					.450				
10.50					.440				
11.00	.124	....	.216	.140	.478				
11.10					.468				
11.20					.438				
11.30	.116	.146	.134	.184	.440				
11.40					.409				
11.50					.470				
12.00	....	....	....	....	.480	.436	.330	.212	.210
12.10					.450	.426	.326	.218	.112
12.20					.498	.416	.318	.178	.084
12.30	....	....	....	....	.498	.426	.308	.200	.070
12.40					.476	.404	.300	.182	.130
12.50					.460	.432	.324	.192	.090
1.00	....	....	....	....	.492	.428	.314	.190	.104
1.10					.516	.414	.306	.206	.104

DRAUGHT PRESSURE. INCHES OF WATER. — *Continued.*

Date, January 14–15, 1896. Nos. 149–151.

Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.	Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.
1.20					.470	10.50					.416
1.30	.118	.178	.196	.166	.500	11.00	.140	.182	.208	.186	.501
1.40					.450	11.10					.525
1.50					.478	11.20					.567
2.00	.122	.190	.192	.142	.478	11.30	.176	.184	.068	.084	.533
2.10					.492	11.40					.547
2.20					.482	11.50					.565
2.30	.128	.192	.188	.176	.454	12.00	....	.222	.202	.186	.571
2.40					.460	12.10					.560
2.50					.488	12.20					.577
3.00	.124	.244	.204	.230	.508	12.30	....	.174	.196	.162	.556
3.10					.484	12.40					.536
3.20					.486	12.50					.464
3.30	.160	.230	.224	.224	.534	1.00	....	.218	.228	.144	.461
3.40					.474	1.10					.451
3.50					.504	1.20					.458
4.00	.140	.216	.216	.184	.532	1.30	....	.202	.196	.138	.453
4.10					.528	1.40					.457
4.20					.578	1.50					.453
4.30	.146	.232	.248	.196	.458	2.00	....	.226	.254	.186	.561
4.40					.506	2.10					.577
4.50					.564	2.20					.559
5.00	.054	.198	.218	.180	.492	2.30	....	.202	.226	.164	.568
5.10					.540	2.40					.531
5.20					.472	2.50					.525
5.30	.158	.230	.238	.190	.494	3.00	....	.240	.260	.234	.566
5.40					.572	3.10					.571
5.50					.560	3.20					.420
6.00	.168	.274	.270	.244	.500	3.30	....	.216	.224	.186	.545
6.10					.527	3.40					.536
6.20					.545	3.50					.497
6.30	.140	.214	.236	.200	.544	4.00	....	.264	.256	.214	.511
6.40					.544	4.10					.561
6.50					.507	4.20					.560
7.00	.114	.264	.294	.254	.555	4.30	....	.224	.224	.186	.563
7.10					.344	4.40					.572
7.20					.542	4.50					.546
7.30	.116	.198	.200	.168	.576	5.00	....	.254	.276	.200	.574
7.40					.470	5.10					.567
7.50					.454	5.20					.532
8.00	.152	.226	.252	.226	.555	5.30	....	.240	.242	.198	.574
8.10					.555	5.40					.550
8.20					.559	5.50					.540
8.30	.080	.124	.128	.100	.604	6.00	....	.256	.258	.214	.580
8.40					.567	6.10					.575
8.50					.490	6.20					.586
9.00	.164	.256	.260	.224	.556	6.30	....	.182	.200	.162	.496
9.10					.563	6.40					.585
9.20					.536	6.50					.530
9.30	.132	.198	.218	.174	.538	7.00	....	.230	.078	.170	.579
9.40					.553	7.10					.586
9.50					.325	7.20					.601
10.00	.148	.224	.236	.194	.514	7.30	....	.286	.252	.228	.619
10.10					.515	7.40					.615
10.20					.523	7.50					.611
10.30	.082	.118	.120	.086	.408	8.00	....	.380	.166	.254	.580
10.40					.370						

SUMMARY OF A 23¾-HOUR BOILER TEST.

Date, January 15, 1896, 8.30 A.M., to January 16, 8.15 A.M. Nos. 152–154.

Time.	Pressures.		Temperatures. °C.					Weights.			Results of calorimeter experiments.	Remarks.
	Barometer. (Lbs. per sq. in.)	Steam gauge.	Outside air.	Flue.	Feed before.	Feed after.	Temperature fire room.	Lbs. of water. (Boiler No. 5.)	Lbs. of fuel. (Boiler No. 5.)	Average lbs. of air. (Boiler No. 5, for 15 minutes.)		
Jan. 15. 8.30 to 4.	14.88	74.6	4.5	189	6.8	30.1	21.6	18,851	1,960	1,157	.993	Ash and clinker. 253
Jan. 15. 4 to 12.	14.91	73.4	—.5	190	7.7	27.3	25.1	17,782	1,960	1,049	.994	387
Jan. 16. 12 to 8.15.	14.95	73.3	—4.2	192	8.2	30.5	23.6	17,971	2,310	1,263	.994	228
Total,		221.3	—.2	571	22.7	87.9	70.3	54,604	6,230	3,469		868
Average,	14.91	73.8	—.1	190	7.6	29.3	23.4			1,156	.994	

		Boiler No. 5.
1.	Description of boiler: Horizontal multitubular.	
2.	Grate surface, No. 5, 60⅝ in. by 61½ in. Area, feet	25.9
3.	Water-heating surface, feet	507.5
4.	Ratio of water-heating surface to grate surface	19.6
5.	Pounds coal fired, including coal equivalent of wood	6,230
6.	Unburned fuel	0
7.	Coal burned, including coal equivalent of wood	6,230
8.	Average coal burned for 15 minutes	65.58
9.	Total refuse from coal	868
10.	Total combustible	5,362
11.	Average combustible for 15 minutes	56.44
12.	Average pounds of air for 15 minutes	1,156
13.	Air per pound of coal	17.6
14.	Air per pound of combustible	20.4
15.	Quality of steam, saturated steam taken as unity	.994
16.	Total water pumped into boiler and apparently evaporated	54,604
17.	Water apparently evaporated per pound of coal	8.76
18.	Water actually evaporated, corrected for quality of steam	54,277
19.	Equivalent water evaporated into dry steam, from and at 212° F.	65,579
20.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of coal	10.52
21.	Equivalent water evaporated into dry steam, from and at 212° F., per pound of combustible	12.23
22.	Coal burned per square foot of grate surface per hour	10.13
23.	Water evaporated, from and at 212° F., per square foot of heating surface per hour	5.44

Analysis of Coal.		Analysis of Ash.	
Carbon,	83.40%	Carbon,	20.9%
Hydrogen,	2.00%	Hydrogen,	0.4%
Moisture,	1.07%	Ash,	77.5%
Ash,	8.75%		

During this test 52 tubes were plugged, cutting down the heating surface 605.8 square feet, and leaving 507.5 square feet. This test was 23.75 hours long.

GAS ANALYSIS.

Date, January 15–16, 1896. Nos. 152–154.

Time.	Over Grate.				Over Bridge Wall.				Back of Boiler.				Flue.			
	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.	CO_2.	O.	CO.	N.
9.00	16.0	3.0	1.2	79.8	12.2	8.6	0.6	78.6	9.4	9.6	0.2	80.8	9.4	7.4	1.2	82.0
10.00	17.6	1.6	0.8	80.0	11.6	8.0	0.2	80.2	9.2	9.8	0.1	80.9	5.8	11.0	0.0	83.2
11.00	13.6	6.2	0.0	80.2	17.6	2.4	0.1	79.9	8.8	10.2	0.1	80.9	7.3	12.5	0.0	80.2
12.00	13.6	6.0	0.0	80.4	7.4	12.2	0.1	80.3	9.0	10.2	0.1	80.7	7.7	12.1	0.0	80.2
1.00	....	....	...	79.2	....	....	...	....	.. .	....	...	....	...	....	...	....
2.00	10.0	10.4	0.4	79.2	9.2	11.8	0.4	78.6	8.9	11.3	0.1	79.7	6.3	12.9	0.0	80.8
3.00	8 8	11.2	0.0	80.0	10.5	10.1	0.0	79.4	8.6	11.8	0.2	79.4	7.4	12.1	0.9	79.6
4.00	11.2	9.9	0.2	78.7	11.7	9.3	0.6	78.4	4.0	16.0	0.2	79.2	...	....	...	....
5.00	7.1	13.9	0.2	78.8	12.6	9 3	0.4	77.7	8.8	10.5	0.1	80.6	...	....	...	....
6.00	11.2	8.8	0.2	79.8	14.8	6.0	0.4	78.8	7.4	13.6	0.1	78.9	...	....	...	....
7.00	14.8	6.2	0.2	78.8	14.8	7.2	0.3	77.7	10.0	10.8	0.2	79.0	...	....	...	....
8.00	17.2	0.6	0.2	80.0	15.6	6.4	0.3	77.7	11.0	9.6	0.2	79.2	...	....	...	....
9.00	18.4	2.2	0.2	79.2	14.8	4.2	0.2	80.8	11.2	9.4	0.2	79.2	...	....	...	....
10.00	12.2	8.6	0.2	79.0	11.7	8.5	0.4	79.4	13.0	8.0	0.1	78.9	...	....	...	....
11.00	18.4	0.8	1.4	79 4	15.7	8.5	0.4	75.4	11.4	8.6	0.0	80.0	...	....	...	....
12.00	13.7	5.7	1.0	79.6	14.6	5.4	0.4	79.6	11.2	10.2	0.2	78.4	...	....	...	....
1.00	17.8	0.8	2.2	79.2	14.8	4.8	0.4	80.0	12.4	8.8	0.3	78.5	...	....	...	....
2.00	16.0	3.6	0.3	80.1	18.4	1.8	0.4	79.4	12.0	8.3	0.0	79.7	...	....	...	....
3.00	13.8	4.2	0.2	81.8	14.4	3.2	0.4	82.0	10.2	10.6	0.2	79.0	...	....	...	....
4.00	15.8	3.8	0.0	84.4	12.6	7.0	0.0	80.4	10.1	9.9	0.3	79.7	...	....	...	....
5.00	5.0	13.4	0.3	81.3	13.2	6.6	0.4	79.8	10.0	10.5	0.2	79.3	...	....	...	....
6.00	10.0	8.8	0.2	81.0	13.0	8.0	0.4	78.6	9.6	10.2	0.0	80.2	...	...	...	....
7.00	1.6	12.4	2.0	84.0	10.0	9.6	0.2	80.2	10.6	10.6	0.0	78.8	...	....	...	....
8.00	7.0	2.2	1.0	89.8	5.4	11.8	0.4	82.4	3.9	17.2	0.3	78.6	...	....	...	....

TEMPERATURE. °CENT.

Date, January 15–16, 1896. Nos. 152–154.

Time.	Flue.	Stack. 1st landing.	Stack. 2d landing.	Stack. 3d landing.	Stack. 4th landing.	Time.	Flue.	Time.	Flue.
8.30	168	....	....	....	....	5.00	199	2.30	200
8.45	202	....	....	....	....	5.15	192	2.45	206
9.00	208	....	....	....	....	5.30	192	3.00	203
9.15	204	....	....	....	....	5.45	196	3.15	190
9.30	194	....	....	....	....	6.00	194	3.30	180
9.45	204	....	....	....	....	6.15	198	3.45	199
10.00	202	....	....	....	....	6.30	189	4.00	199
10.15	198	....	....	....	....	6.45	190	4.15	190
10.30	190	....	....	....	....	7.00	189	4.30	178
10.45	196	....	....	....	....	7.15	183	4.45	200
11.00	198	....	....	....	....	7.30	175	5.00	198
11.15	194	....	....	....	....	7.45	191	5.15	194
11.30	186	....	....	....	....	8.00	193	5.30	194
11.45	196	....	....	....	....	8.15	188	5.45	189
12.00	192	....	....	....	....	8.30	180	6.00	194
12.15	189	....	....	....	....	8.45	193	6.15	188
12.30	178	....	....	....	....	9.00	194	6.30	184
12.45	194	....	....	....	....	9.15	189	6.45	198
1.00	195	200	....	169	172	9.30	181	7.00	204
1.10	....	206	202	179	175	9.45	193	7.15	193
1.15	192	....	....	....	....	10.00	193	7.30	180
1.20	....	211	204	179	179	10.15	191	7.45	148
1.30	176	208	205	178	184	10.30	188	8.00	181
1.40	....	182	179	173	163	10.45	198	8.15	....
1.45	191	....	....	....	....	11.00	197	....	....
1.50	....	....	182	177	166	11.15	193	....	....
2.00	194	....	....	....	....	11.30	173	....	....
2.15	194	....	....	....	....	11.45	169	....	....
2.30	191	....	....	....	....	12.00	189	....	....
2.45	198	....	....	....	....	12.15	188	....	....
3.00	199	....	....	....	....	12.30	178	....	....
3.15	193	....	....	....	....	12.45	189	....	....
3.30	171	....	....	....	....	1.00	194	....	....
3.45	193	....	....	....	....	1.15	189	....	....
4.00	192	....	....	....	....	1.30	189	....	....
4.15	194	....	....	....	....	1.45	213	....	....
4.30	197	....	....	....	....	2.00	210	....	....
4.45	199	....	....	....	....	2.15	204	....	....

DRAUGHT PRESSURE. INCHES OF WATER.

Date, January 15–16, 1896. Nos. 152–154.

Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.	Stack.			
						1st landing.	2d landing.	3d landing.	4th landing.
8.30	....	.316	.190	.160	.197	....	....	....	....
8.40					.526				
8.50					.525				
9.00	.126	.174	.136	.102	.521	....	....	....	....
9.10					.643				
9.20					.458				
9.30	.090	.130	.174	.096	.528	....	....	....	....
9.40					.512				
9.50					.554				
10.00	.124	.166	.176	.112	.506	....	....	....	....
10.10					.529				
10.20					.516				
10.30	.114	.188	.170	.160	.511	....	....	....	....
10.40					.456				
10.50					.435				
11.00	.092	.128	.122	.106	.442	....	....	....	....
11.10					.435				
11.20					.497				
11.30	.150	.188	.200	.166	.514	....	....	....	....
11.40					.525				
11.50					.524				
12.00	.112	.124	.140	.210	.465	....	....	....	....
12.10					.500				
12.20					.605				
12.30	.114	.152	.162	.142	.521	....	....	....	....
12.40					.508				
12.50					.508				
1.00	....	....	....	....	.508	.404	.306	.240	.106
1.10					.483	.454	.334	.212	.130
1.20					.448	.450	.348	.222	.114
1.30	....	....	....	....	.435	.448	.322	.206	.108
1.40					.442	.426	.310	.230	.100
1.50					.436	.440	.300	.208	.120

DRAUGHT PRESSURE. INCHES OF WATER. — *Continued.*

Date, January 15–16, 1896. Nos. 152–154.

Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.	Time.	Over grate.	Bridge wall.	Under back of boiler.	Back of boiler.	Uptake.
2.00	.088	.124	.128	.100	.442	11.20					.445
2.10					.479	11.30	.106	....	.096	.014	.190
2.20					.482	11.40					.190
2.30	.114	.134	.182	.144	.479	11.50					.475
2.40					.482	12.00	.578	....	.136	....	.487
2.50					.479	12.10					.476
3.00	.096	.122	.150	.106	.487	12.20					.494
3.10					.475	12.30	.142	....	.178	.174	.495
3.20					.477	12.40					.528
3.30	.126	.150	.198	.128	....	12.50					.462
3.40					.532	1.00	.100	....	.184	....	.541
3.50					.523	1.10					.459
4.00	.074	....	.158	.116	.509	1.20					.487
4.10					.526	1.30	.146	....	.256	.188	.491
4.20					.482	1.40					.484
4.30	.094	....	.176	.116	.450	1.50					.584
4.40					.468	2.00	.100	....	.190	....	.594
4.50					.468	2.10					.592
5.00	.080	....	.142	.092	.476	2.20					.496
5.10					.454	2.30	.144	....	.232	.190	.588
5.20					.435	2.40					.593
5.30	.032	....	.196	.138	.481	2.50					.598
5.40					.410	3.00	.120	....	.190	....	.598
5.50					.416	3.10					.587
6.00	.592	....	.150	.104	.410	3.20					.514
6.10					.397	3.30	.164	....	.190	.160	.509
6.20					.395	3.40					.593
6.30	.672	....	.182	.138	.412	3.50					.535
6.40					.440	4.00	.102	....	.178	....	.533
6.50					.408	4.10					.509
7.00	.548	....	.136	.120	.401	4.20					.517
7.10					.417	4.30	.144	....	.206	.172	.536
7.20					.435	4.40					.537
7.30	.044	....	.192	.154	.385	4.50					.556
7.40					.432	5.00	.142	....	.176	....	.593
7.50					.420	5.10					.590
8.00	.474	....	.192	.100	.430	5.20					.519
8.10					.420	5.30	.122	....	.204	.174	.516
8.20					.420	5.40					.536
8.30	.664	....	.196	.148	.420	5.50					.599
8.40					.424	6.00	.122	....	.192	....	.595
8.50					.430	6.10					.590
9.00	.470	....	.166	.120	.430	6.20					.585
9.10					.430	6.30	.144	....	.260	.180	.592
9.20					.430	6.40					.603
9.30	.072	....	.180	.150	.425	6.50					.594
9.40					.430	7.00	.120	....	.244	....	.593
9.50					.438	7.10					.590
10.00	.538	....	.170	.140	.434	7.20					.515
10.10					.430	7.30	.118	....	.144	1.26	.568
10.20					.430	7.40					....
10.30	.524	....	.188	.166	.455	7.50					.588
10.40					.448	8.00	.122	....	.200	....	.602
10.50					.440	8.10					.596
11.00	.522	....	.186	.148	.418	8.15					.560
11.10					.429						

PULSOMETER TESTS.

TESTS ON A NO. 4 PULSOMETER.

Made by the Pulsometer Steam Pump Company, of New York City.

Date.	Number of test.	Total lift. (Feet.)	Steam pressure at pulsometer. (Gauge.)	Steam used per hour. (Pounds.)	Water pumped per hour, including steam.	Temperature at suction. °C.	Temperature at discharge. °C.	Work done by pulsometer. (Foot-pounds.)	Total heat given up by steam. (B. T. U.)	Efficiency. (Per cent.)	Duty foot-pounds per 1,000,000. (B. T. U.)	Capacity. (Gallons per minute.)
1896.												
Feb. 13	1	18.50	17.3	189.0	18,360	22.6	28.3	337,800	209,100	.21	1,615,000	36.7
Feb. 13	2	18.78	25.7	193.6	20,850	28.2	33.4	389,900	219,200	.23	1,831,000	41.7
Feb. 14	3	17.30	34.7	192.4	18,030	27.7	33.6	310,300	219,100	.19	1,456,000	36.1
Feb. 14	4	18.16	37.5	192.0	17,500	32.3	37.9	316,200	211,400	.19	1,495,000	35.0
Feb. 17	5	22.22	11.5	196	11,890	25.3	34.5	262,300	214,800	.16	1,222,000	23.8
Feb. 17	6	20.39	31.5	197.4	8,176	31.9	43.5	164,700	214,800	.10	767,000	16.4
Feb. 18	7	22.90	27.4	197.2	10,170	28.9	39.0	231,000	215,700	.14	1,071,000	20.3
Feb. 18	8	25.15	29.5	191.5	14,700	30.9	37.8	368,270	210,100	.23	1,753,000	29.4
Feb. 20	9	23.48	28.9	195.2	14,610	28.7	36.7	341,300	214,500	.21	1,591,000	29.2
Feb. 21	10	24.15	27.7	195.3	13,340	31.0	39.0	320,300	213,700	.16	1,221,000	26 7
Feb. 21	11	24.50	19.0	195.7	14,530	32.8	39.8	354,400	213,100	.21	1,663,000	29 08
Feb. 24	12	25.32	37.8	196.6	17,530	26.0	32.9	442,200	218,100	.24	1,836,000	35.07
Feb. 24	13	21.02	33.9	197.1	9,906	36.0	46.2	206,650	215,200	.12	960,400	19.80
Feb. 25	14	24.54	33.4	197.2	16,690	31.4	37.0	408,000	217,000	.24	1,880,000	33.40
Feb. 27	15	27.61	61.2	371.0	37,040	38.3	45.7	1,019,000	405,400	.32	2,514,000	74.11
Feb. 28	16	25.32	58.4	412.1	31,230	45.0	53.4	786,600	442,800	.23	1,777,000	62.48
Mar. 2	17	28.14	41.3	474.6	37,900	35.8	44.2	1,062,000	517,200	.26	2,052,000	75.83
Mar. 3	18	23.22	50.3	497.4	31,110	39.4	49.9	713,400	538,500	.17	1,325,000	62.24
Mar. 5	19	27.28	49.5	480.6	35,950	34.5	44.0	985,500	525,400	.24	1,876,000	71.93
Mar. 5	20	27.41	42.5	419.4	35,660	35.7	43.5	972,900	458,000	.25	1,938,000	71.40
Mar. 6	21	29.61	54.1	421.5	39,680	35.8	43.2	1,171,000	462,000	.33	2,534,000	79.4
Mar. 6	22	24.86	50.8	476 6	33,020	42.1	51.4	815,800	514,800	.20	1,585,000	67.60
Mar. 10	23	29.42	50.1	468.2	40,150	27.2	35 5	1,176,000	519,300	.29	2,265,000	80.32
Mar. 10	24	25.93	26 3	246.0	31,110	41.5	47.4	803,900	265,800	.39	3,024,000	62.24
Mar. 12	25	27.51	30.2	304.5	37,760	24.5	31.9	1,035,000	338,200	.44	3,436,000	75.55
Mar. 12	26	25.92	29.2	324.0	33,790	32.6	38.9	872,200	354,800	.32	2,458,000	67.61
Mar. 13	27	29.46	26.8	285.7	39,660	25.3	29.9	1,130,000	316,500	.46	3,570,000	79.35
Mar. 13	28	28.68	30.2	293.9	38,700	32.7	38.0	1,106,000	322,400	.44	3,432,000	77.44
Mar. 16	29	29.23	28.5	303.6	38,360	25.1	29.6	1,118,000	337,600	.43	3,311,000	76.74
Mar. 16	30	32.17	28.1	332.5	45,320	19.4	24.3	1,454,000	372,400	.50	3,906,000	90.67
Mar. 17	31	31.46	30.5	299.5	43,680	23.3	28.5	1,371,000	333,700	.53	4,109,000	87.40
Mar. 17	32	29.64	30.1	313.5	40,020	32.3	37.5	1,183,000	344,200	.44	3,437,000	80.08
Mar. 19	33	29.05	24.5	253.6	39,550	23.4	28.0	1,146,000	282,200	.52	4,062,000	79.15
Mar. 19	34	30.23	30.9	336.1	41,410	29.2	34.3	1,248,000	371,100	.43	3,363,000	82.86
Mar. 20	35	30.36	31.5	330 0	41,660	31.0	36.4	1,137,000	363,400	.40	3,129,000	83.35
Mar. 20	36	27.08	31.7	300.2	34,200	36.8	42.4	821,000	327,200	.32	2,510,000	68.43
Mar. 23	37	31.25	31.2	305.8	44,210	22.8	27.9	1,378,000	341,300	.52	3,655,000	88.46
Mar. 23	38	28.63	28.6	330.6	36,550	36.2	41.9	1,043,000	360,400	.37	2,893,000	73.12
Mar. 24	39	29.66	21.9	258.8	40,960	28.2	32.8	1,212,000	284,700	.55	4,258,000	81.96
Mar. 24	40	28.64	29.9	319.1	36,910	37.3	42.9	1,054,000	347,300	.39	3,036,000	73.85
Mar. 26	41	31.56	28.6	340.1	43,350	22.2	27.4	1,364,000	379,600	.46	3,593,000	86.73
Mar. 27	42	29.56	28.8	315.8	41,160	28.1	32.9	1,212,000	349,300	.45	3,476,000	82.36
Mar. 27	43	28.41	26.1	310.4	37,230	34.9	40.1	1,054,000	339,000	.40	3,110,000	74.49

Water was drawn from a reservoir about 8 feet below the pump. The discharge pipe was 2½" diameter.

Tests on the Flow of Steam.

EXPERIMENTS ON THE FLOW OF STEAM THROUGH AN ORIFICE ¼″ IN DIAMETER.

Date.	Calorimeter Test.															
	Boiler pressure.	Calorimeter pressure.	Calorimeter temperature.	Value of x.	Boiler pressure.	Back pressure.	Orifice pressure.	Barometer pressure.	Weight of condensed steam.	Steam per hour by experiment.	By thermodynamic equation.	By Napier's formula.	Coefficient of flow from thermo equation.	Coefficient by Napier's equation.	Absolute back pressure.	Absolute boiler pressure.	Absolute orifice pressure.	Absolute boiler pressure.
1895.																		
Oct. 7	105.1	2.4	143.6	.995	95.6	51.7	55.1	14.5	268.4	268.4	278.8	277.9	.963	.966	.601	.632		
Oct. 8	78.4	2.0	137.8	.998	87.5	46.0	50.3	14.5	252.7	252.7	258.2	257.6	.979	.981	.593	.635		
Oct. 9	91.0	2.6	140.7	.998	87.5	51.0	53.4	14.7	249.3	249.3	254.0	252.3	.982	.988	.643	.666		
Oct. 9	76.7	0.8	137.5	.998	89.2	56.2	57.8	14.7	246.2	246.2	253.6	249.4	.971	.987	.682	.698		
Oct. 10	102.5	3.3	141.5	.994	100.5	52.5	57.3	14.9	280.1	280.1	289.9	291.3	.966	.962	.584	.626		
Oct. 11	95.0	1.4	141.9	.997	93.1	46.8	52.2	14.9	268.3	268.3	264.2	272.6	1.016	.984	.571	.621		
Oct. 14	103.4	2.1	142.1	.996	100.9	70.5	71.8	14.6	262.3	262.3	270.5	262.1	.970	1.007	.737	.748		
Oct. 16	96.1	2.1	141.4	.996	95.9	50.4	54.8	14.7	273.4	273.4	278.2	280.6	.983	.974	.589	.628		
Oct. 16	96.1	3.0	141.5	.997	95.7	53.5	56.8	14.7	268.0	268 0	276.1	276.5	.971	.969	.619	.649		
Oct. 17	96.0	3.0	141.2	.996	95.6	55.8	57.5	14.6	134.6	269.2	274.5	272.7	.981	.987	.639	.646		
Oct. 18	94.2	2.9	141.0	.996	94.0	68.4	68.7	14.8	235.6	235.6	248.5	238.2	.948	.989	.764	.767		
Oct. 18	94.8	2.8	141.7	.998	95.6	42.1	52.7	14.8	272.1	272.1	279.4	278.6	.974	.977	.516	.612		
Oct. 21	93.7	2.8	141.0	.996	93.0	49.7	53.4	14.7	265.5	265.5	269.5	272.1	.985	.976	.598	.632		
Oct. 21	93.3	2.8	141.6	.997	93.0	45.0	51.6	14.8	267.3	217.3	270.8	272.0	.985	.983	.555	.616		
Oct. 23	93.7	3.0	140.7	.996	93.5	55.2	57.2	14.7	195.2	260.1	267.8	265.6	.971	.979	.648	.667		
Oct. 24	93.5	2.9	140.7	.996	93.9	56.8	58.7	14.9	255.4	255.4	268 1	265.8	.953	.961	.659	.676		
Oct. 25	96.2	3.1	140.9	.995	93.1	64.4	64.5	14.6	243.2	243.2	256.0	245.2	.950	.992	.734	.735		
Oct. 25	94.3	3.2	141.2	.996	94.1	62.0	62.8	14.5	248.0	248.0	260.7	255.4	.951	.971	.704	.712		
Oct. 28	94.2	3.1	141.0	.996	93.7	56.3	58.3	14.6	264.0	264.0	266.1	265.3	.992	.995	.655	.673		
Oct. 29	95.9	3.1	140.8	.995	95.7	65.8	66.7	14.8	249.5	249.5	260.2	253.1	.959	.986	.729	.737		
Nov. 4	96.1	3.3	142.4	.996	96.9	39.9	52.9	15.0	273.4	273.4	282.1	282.6	.969	.967	.491	.607		
Nov. 5	86.0	2.8	140.9	.998	95.7	47.0	53.5	15.0	271.3	271.3	275.8	279.3	.984	.971	.560	.619		
Nov. 6	96.4	3.1	142.3	.997	96.4	48.4	54.1	15.0	283.3	274.2	281.4	281.2	.975	.975	.569	.621		
Nov. 6	95.8	3.1	140.4	.995	97.1	72.3	72.6	14.9	238.8	238.8	256.3	239.6	.931	.996	.779	.781		
Nov. 7	86.8	2.7	138.9	.997	96.6	66.4	67.5	14.8	246.8	246.8	261.5	255.1	.944	.967	.729	.739		
Nov. 8	96.9	3.4	141.2	.995	96.7	66.4	67.3	14.8	249.4	249.4	262.0	254.5	.951	.980	.728	.736		
Nov. 8	98.2	3.5	141.3	.995	97.1	69.4	69.8	14.8	242.5	242.5	258.6	243.1	.938	.998	.755	.756		
Nov. 11	95.4	3.0	142.5	.997	96.1	51.7	55.3	15.0	270.1	270.1	277.9	280.3	.972	.963	.600	.633		
Nov. 14	85.5	3.0	139.3	.996	86.4	50.2	51.8	14.9	244.3	244.3	252.7	250.2	.967	.976	.643	.658		
Nov. 15	86.8	2.7	139.5	.997	85.5	51.4	52.9	14.6	237.0	237.0	247.0	244.5	.959	.970	.659	.674		
Nov. 18	87.1	2.7	140.3	.997	85.7	46.8	49.8	14.7	237.1	244.4	252.1	252.0	.970	.970	.613	.628		
Nov. 21	85.6	1.4	138.6	.997	95.8	54.5	55.3	14.7	236.6	236.6	245.6	239.8	.963	.987	.689	.697		
Nov. 22	85.5	2.7	139.9	.997	85.2	40.5	46.7	15.0	248.4	248.4	253.3	251.9	.981	.986	.554	.616		
Nov. 25	85.6	1.3	139.5	.997	85.2	43.8	47.7	14.9	236.7	236.7	252.7	252.9	.937	.936	.587	.625		

For description of orifice, see Technology Quarterly, Vol. VIII, No. 1.

Tests on Davis Pump.

Date.	Revolutions per minute of driving shaft.	Revolutions per minute of pump shaft.	Suction head in feet.	Discharge head in feet.	Velocity head in feet.	Total head in feet.	Power given to pump. (H. P.)	Work done by pump. (H. P.)	Efficiency. (Per cent.)	Capacity. (Gallons per minute.)	Vertical distance between gauges.
1895.											
Oct. 24	106.2	19.4	6.92	63.74	.11	71.83	1.59	1.09	68.2	59.8	1.06
Oct. 25	105.0	19.2	6.58	55.43	.11	63.18	1.45	.95	65.5	59.4	1.06
Oct. 25	105.8	19.4	6.80	57.97	.12	65.95	1.46	1.01	69.5	60.8	1.06
Oct. 26	104.5	19.1	7.03	66.05	.11	74.25	1.61	1.11	68.9	59.2	1.06
Oct. 28	103.8	19.00	6.69	67.28	.11	77.14	1.13	1.14	71.3	58.6	1.06
Oct. 30	101.4	18.57	7.14	76.21	.10	84.51	1.69	1.21	72.0	57.0	1.06
Oct. 31	100.4	18.38	7.14	82.91	.10	90.21	1.88	1.29	68.8	56.6	1.06
Nov. 4	100.9	.....	6.92	89.34	.10	97.92	2.00	1.41	71.0	57.3	1.06
Nov. 4	104.0	19.04	6.92	90.53	.10	98.61	2.06	1.48	72.1	59.5	1.06
Nov. 5	102.0	18.7	6.80	97.23	.10	105.19	2.09	1.53	73.2	57.5	1.06
Nov. 6	98.2	14.00	6.92	99.08	.09	107.15	2.05	1.50	73.1	55.4	1.06
Nov. 6	99.2	18.2	6.83	98.61	.09	106.59	2.03	1.48	72.9	55.0	1.06
Nov. 7	100.4	.....	7.26	104.39	.11	112.82	2.09	1.61	76.7	56.4	1.06
Nov. 8	101.3	18.5	7.37	125.09	.10	133.62	2.50	1.94	77.5	57.5	1.06
Nov. 14	103.7	19.0.	6.92	83.60	.10	91.68	1.74	1.34	77.6	58.3	1.06
Nov. 15	106.2	19.4	8.17	133.49	.10	142.82	3.05	2.12	69.4	58.8	1.06
Nov. 18	110.1	20.2	6.24	65.36	.11	72.77	1.58	1.14	72.7	62.3	1.06
Nov. 18	109.8	20.1	7.14	63.97	.11	72.28	1.57	1.14	72.8	62.7	1.06
Nov. 19	111.5	20.4	6.61	30.95	.11	38.73	.94	.62	65.6	63.3	1.06
Nov. 20	111.3	20.4	7.26	31.72	.11	79.35	.82	.62	76.0	62.8	1.06

TEST ON BELT MACHINE, USING 4″ DOUBLE LEATHER BELT.

Date.	Number of test.	Horse power.	Speed of east belt. (Feet per minute.)	Speed of west belt. (Feet per minute.)	Speed of circumference of southeast pulley.	Speed of circumference of northeast pulley.	Speed of circumference of southwest pulley.	Speed of circumference of northwest pulley.	Sum of tensions. (East belt.)	Difference of tensions. (East belt.)	Tension tight side. (East belt.)	Tension loose side. (East belt.)	Tension per inch of width, tight side. (East belt.)	Tension per inch of width, loose side. (East belt.)	Sum of tensions. (West belt.)	Difference of tensions. (West belt.)	Tension tight side. (West belt.)	Tension loose side. (West belt.)	Tension per inch of width, tight side. (West belt.)	Tension per inch of width, loose side. (West belt.)	Coefficient of friction. (East belt.)	Coefficient of friction. (West belt.)
Nov. 7	1	3.66	2,214	2,203	2,199	2,202	2,199	2,196	400	54.6	227.3	172.7	56.8	43.2	400	54.9	227.5	172.5	56.9	43.1	.087	.088
Nov. 7	2	5.36	2,203	2,191	2,189	2,192	2,189	2,185	405	80.3	242.6	162.4	48.5	40.6	405	80.7	242.8	162.2	48.5	40.5	.128	.128
Nov. 8	1	7.14	2,224	2,210	2,208	2,213	2,208	2,204	407	105.9	256.5	150.5	64.1	37.6	407	106.6	256.8	150.2	64.2	37.5	.170	.171
Nov. 8	2	8.71	2,186	2,170	2,169	2,175	2,169	2,163	411	131.6	271.3	139.7	67.8	34.9	411	132.5	271.8	139.2	67.9	34.8	.211	.213
Nov. 8	3	8.63	2,161	2,144	2,150	2,151	2,150	2,139	411	131.9	271.5	139.6	67.9	34.9	411	132.9	272.0	139.2	68.0	34.8	.212	.214
Nov. 8	4	6.98	2,174	2,157	2,158	2,163	2,158	2,153	407	105.9	256.5	150.6	64.1	37.6	407	106.8	256 9	150.1	64.2	37.5	.169	.171
Nov. 11	1	5.37	2,207	2,196	2,192	2,195	2,192	2,189	404	80.3	242.1	161.9	60.5	40.4	404	80.8	242.4	161.6	60.5	40.4	.128	.128
Nov. 11	2	3.69	2,229	2,220	2,215	2,218	2,215	2,213	400	54.6	227.3	172.7	56.8	43.1	400	54.8	227.4	172.6	56.8	43.1	.087	.088
Nov. 11	3	3.65	2,202	2,195	2,190	2,193	2,190	2,189	452	54.7	253.3	198.7	63.3	49.6	452	54.9	253.4	198.6	63.3	49.6	.077	.077
Nov. 11	4	3.65	2,201	2,196	2,191	2,195	2,191	2,190	452	54.7	253.3	198.7	63.3	49.6	452	54.9	253.4	198.6	63.3	49.6	.077	.077
Nov. 12	1	5.29	2,175	2,163	2,159	2,161	2,159	2,156	454	80.3	267.2	186.8	66.8	46.7	454	80.8	267.4	186.6	66 9	4.66	.114	.112
Nov. 12	2	6.96	2,167	2,154	2,152	2,155	2,152	2,147	455	106.0	280.5	174.5	70.1	43.6	455	106 6	280.8	174.2	70.2	43.5	.151	.152
Nov. 13	3	9.88	2,070	2,054	2,054	2,060	2,054	2,048	459	157.5	308.3	150.8	77.1	37.7	459	158.7	308.9	150.2	77.2	37.5	.227	.229
Nov. 13	4	8.49	2,121	2,107	2,105	2,112	2,105	2,100	457	132.0	294.5	162.5	73.6	40 6	457	132.9	295.0	162.6	73.7	40.6	.189	.190
Nov. 13	1	8.55	2,142	2,129	2,127	2,132	2,127	2,126	459	131.7	295.3	163.6	40.9	40.9	459	132.6	295.8	163.2	40.8	40.8	.185	.187
Nov. 13	2	10.21	2,136	2,124	2,121	2,128	2,121	2,120	464	157.7	310.8	153.1	38.3	38.2	464	158.6	311.3	152.7	38.2	38.1	.225	.226
Nov. 14	1	6.94	2,159	2,147	2,145	2,149	2,145	2,140	450	106.2	278.1	171.9	69.5	42.9	450	106.7	278.4	171.6	69.6	42.9	.153	.154
Nov. 14	2	6.91	2,151	2,137	2,137	2,140	2,137	2,131	453	106.1	279.5	173.5	69.9	43.3	453	106.8	279 9	173.1	70.0	43.2	.152	.153
Nov. 15	1	4.87	2,159	2,167	2,144	2,149	2,144	2,142	450	74.4	262.2	187.8	65.6	46.9	450	74.2	262.1	187.9	65.5	46.9	.106	.106
Nov. 15	2	3.21	2,156	2,167	2,164	2,168	2,164	2,161	450	49.1	249.5	200.5	62.4	50.1	450	48.8	249.4	200.6	62.4	50 1	.069	.069
Nov. 15	3	1.91	2,186	2,176	2,168	2,170	2,168	2,167	500	28 96	264.5	235.5	46.1	58.8	500	29.1	264.5	235.5	46.1	58.8	.038	.038
Nov. 18	1	3.68	2,228	2,219	2,215	2,216	2,215	2,212	500	54.5	277.2	227.7	69.3	55.6	500	54.7	277.4	222.6	69.3	55.6	.070	.070
Nov. 18	2	5.39	2,211	2,202	2,199	2,203	2,199	2,195	508	80.4	294.2	213.8	73.5	53.4	508	80.7	294.4	213.6	73.6	53.4	.101	.102
Nov. 18	3	6.90	2,151	2,136	2,134	2,139	2,134	2,131	510	105.9	307.9	202.1	77.0	50.5	510	106.6	300.3	201.7	77.0	50.4	.135	.136
Nov. 18	4	8.57	2,148	2,151	2,132	2,138	2,132	2,129	512	132.3	322.2	189.8	80.5	47.4	512	132.1	322.0	190.0	80.5	47.7	.168	.168
Nov. 19	1	8.46	2,119	2,106	2,105	2,110	2,105	2,099	510	131.8	320.9	189.1	80.2	47.2	510	132.1	321.3	188.7	80.3	47.1	.170	.169
Nov. 19	2	6.94	2,159	2,147	2,145	2,149	2,145	2,140	508	106.1	307.1	201.0	76.8	50.2	508	106.7	307.4	200.7	76.9	50.1	.135	.136
Nov. 20	2	3.62	2,165	2,157	2,172	2,176	2,172	2,168	503	55.2	279.1	223.9	69.8	55.9	503	55.4	279.2	223.8	69 8	55.9	.070	.071
Nov. 21	1	3.63	2,191	2,184	2,179	2,181	2,179	2,177	300	54.7	117.0	122.7	44.3	30.6	300	54.9	117.4	122.6	44.4	30.6	.117	.118
Nov. 22	1	1.95	2,237	2,232	2,236	2,227	2,226	2,225	600	28.8	314.4	285.6	78.6	71.4	600	28.9	314.4	285.6	78.6	71.4	.031	.031
Nov. 22	2	3.69	2,228	2,219	2,212	2,217	2,212	2,213	600	54.6	327.3	272.7	81.8	68.1	600	54.8	327.4	272.6	81.9	68.1	.058	.058
Nov. 22	3	5.30	2,179	2,168	2,166	2,169	2,166	2,163	600	77.2	338.6	261.4	84.7	65.3	600	77.6	338.8	261.2	84.7	65.3	.082	.083
Nov. 22	4	6.94	2,155	2,145	2,142	2,146	2,142	2,138	605	103.2	354.1	240.9	88.5	60.2	605	103.7	354 3	240.7	88.6	60.1	.122	.123
Nov. 25	1	8.42	2,106	2,094	2,092	2,099	2,092	2,088	600	131.9	366.0	234.1	91.5	58.5	600	132.6	366.3	233.7	91.6	58.4	.145	.143
Nov. 25	2	8.67	2,171	2,161	2,157	2,162	2,157	2,156	600	132.2	366.1	233.9	91.5	58.4	600	132.6	366.3	233.7	91.6	58.4	.143	.143
Nov. 25	3	6 88	2,178	2,169	2,170	2,171	2,170	2,164	600	104.3	352.2	247.8	88.1	61.9	600	105.0	352.5	247.5	88.1	61.8	.112	.113
Nov. 26	1	5.19	2,127	2,117	2,114	2,118	2,114	2,111	600	77.5	338.7	261.3	84.7	65.3	600	77.8	338.9	261.1	84.7	65.2	.083	.085
Nov. 26	2	3.61	2,184	2,175	2,170	2,173	2,170	2,168	600	51.6	325.8	274.2	81.5	68.5	600	51.8	325.9	274 1	81.5	68.5	.055	.053
Nov. 27	1	1.92	2,196	2,191	2,185	2,187	2,185	2,184	650	28.5	339.2	310.8	84.9	77.7	650	28.6	339.3	310.7	84.9	77.6	.028	.028
Nov. 27	2	3.78	2,187	2,182	2,177	2,179	2,177	2,175	650	57.1	353.5	296.5	88.4	74.1	650	57.2	353.6	296.4	88.4	74.1	.054	.054
Nov. 27	3	5.31	2,180	2,171	2,167	2,171	2,167	2,165	650	80.5	365.2	284.7	91.3	71.1	650	80.8	365.4	284.6	91.3	71.1	.079	.079

A brief description of this belt machine was given in Technology Quarterly, Vol. VIII, No. 1.

Engine Tests.

TESTS ON THE TRIPLE EXPANSION ENGINE, 9″–16″–24″ × 30″, RUN AS A COMPOUND.

Horse power.	Steam per H. P. per hour.	Steam through cylinders per hour.	Water by Jackets per Hour.		Revolutions per minute.	Boiler pressure. (Gauge.)	Vacuum in condenser. (Inches mercury.)	Barometer.
			Intermediate pressure cylinder.	Low pressure cylinder.				
1	2	3	4	5	6	7	8	9
52.0	22.67	.....	....	....	83.02	43.5	27.01	30.5
54.67	.....	809.5	....	....	83.38	47.5	26.3	29.87
77.02	.....	1,658.0	....	....	81.05	44.0	25.25	29.36
77.50	.....	1,257.5	....	....	80.73	44.07	25.4	30.20
72.0	21.54	1,549.0	....	....	81.83	44.7	25.8	29.9
78.8	20.96	1,648.5	....	....	81.25	44.1	26.17	30.1
83.01	.....	1,773.0	....	....	80.83	49.0	25.3	29.91
84.18	.....	1,807.0	....	....	80.60	47.1	25.3	29.60
90.1	21.33	1,922.0	....	....	80.23	44.3	25.16	30.32
91.92	21.23	1,949.0	....	....	80.0	43.9	25.2	29.7
92.9	21.29	1,976.5	....	....	80.15	43.8	25.4	29.98
59.46	21.96	1,196.0	....	109.5	85.72	50.5	25.3	29.56
66.32	21.28	1,304.0	....	107.25	82.73	49.0	26.2	29.65
71.18	20.29	1,321.5	....	122.42	82.50	49.8	26.0	29.70
72.47	20.97	1,389.0	....	131.1	82.30	48.4	25.2	29.50
76.39	20.42	1,408.0	....	151.6	82.03	48.4	26.64	30.04
77.16	20.65	1,456.5	....	136.7	82.10	48.4	25.8	30.03
78.14	20.41	1,455.5	....	139.71	81.95	51.3	25.7	29.90
79.04	20.42	1,481.5	....	132.2	81.78	48.5	25.7	29.84
80.30	20.14	.....	....	104.1	81.60	47.5	25.5	29.80
85.27	19.95	1,589.5	....	111.97	81.22	48.2	25.8	29.71
94.69	19.78	1,729.5	....	137.75	80.90	48.0	25.7	30.38
95.05	19.35	1,702.5	....	126.6	80.92	47.5	25.6	29.50
103.03	20.13	1,962.0	....	112.3	82.0	44.3	24.3	29.35
107.93	19.88	2,027.0	....	188.9	82.28	48.9	24.2	29.8
62.82	19.39	1,072.5	59.7	86.2	83.07	48.0	26.1	30.48
67.43	19.78	1,179.5	57.05	97.29	85.27	50.63	24.6	29.40
80.30	18.70	1,352.5	149.1	149.1	81.85	48.3	25.4	29.76
87.68	19.07	1,520.5	50.99	100.74	81.23	47.5	25.6	29.80
90.47	18.35	1,504.5	53.4	102.0	81.05	47.5	25.8	29.82
94.39	18.40	1,582.0	53.0	101.3	80.93	47.7	25.7	29.48

TESTS ON THE TRIPLE EXPANSION ENGINE, 9″–16″–24″ × 30″, RUN AS A COMPOUND. — *Continued.*

INTERMEDIATE CYLINDER.

Initial pressure.	Per cent. cut-off.	Pressure at cut-off.	Pressure at release.	Pressure at compression.	Per cent. of steam in the cylinder at cut-off.	Per cent. of steam in the cylinder at release.	M. E. P. crank.	M. E. P. head.	Horse power.
10	11	12	13	14	15	16	17	18	19
40.0	7.4	37.2	4.3	—4.4	71.56	85.75	13.59	12.21	32.4
47.0	7.6	41.7	—3.3	—2.3	59.89	79.25	11.87	12.15	30.25
26.7	21.1	38.9	2.7	2.8	70.70	82.27	15.96	17.49	40.98
46.9	21.0	40.5	2.7	2.8	71.93	83.16	16.32	18.18	42.10
41.3	15.7	37.0	0.2	—1.2	63.26	80.12	17.57	17.7	43.6
40.3	20.2	36.8	0.6	0.5	69.40	79.46	19.42	19.18	47.4
47.3	23.3	40.0	4.1	3.5	72.41	84.27	16.99	18.67	43.63
46.9	24.5	42.1	4.6	5.20	76.52	83.67	17.62	18.88	44.49
41.9	30.1	36.4	4.6	4.6	76.0	82.12	19.0	19.8	47.0
40.4	27.9	37.7	4.0	1.7	74.36	79.20	23.37	22.6	55.6
41.0	29.0	37.1	4.6	1.4	74.0	81.0	23.48	22.85	56.1
46.5	8.7	34.0	—2.1	0.7	56.11	86.99	9.19	9.60	24.34
45.9	10.7	41.2	—0.1	1.2	62.79	89.82	10.81	11.46	27.85
47.1	11.7	39.9	—8.0	1.0	63.39	85.76	12.29	12.63	31.07
46.2	12.8	38.8	—0.8	2.8	62.25	80.57	13.39	13.75	33.76
47.3	13.6	43.0	0.3	3.1	67.43	85.08	12.49	13.35	32.04
46.0	13.5	41.3	0.1	1.3	64.38	82.63	13.52	14.80	35.15
46.2	14.5	39.6	0.6	3.3	64.04	84.15	13.36	13.88	33.74
45.9	15.5	40.0	1.4	3.8	65.88	86.51	12.89	13.47	32.58
45.5	16.5	38.2	1.1	2.5	65.56	83.62	14.04	15.74	36.74
47.3	17.2	43.5	1.5	3.0	59.68	81.49	15.02	16.70	38.95
46.9	21.6	42.4	3.3	4.0	73.22	84.06	16.95	18.35	43.17
46.0	22.5	41.0	2.9	4.6	73.73	80.79	16.50	18.12	42.71
43.1	33.0	36.5	7.2	8.6	78.10	87.0	18.71	18.52	46.14
47.2	31.2	40.5	5.7	7.8	79.35	80.62	19.78	17.98	46.92
47.6	7.8	44.2	—3.0	—1.8	69.87	91.65	11.86	12.54	30.67
47.8	10.1	40.9	—1.9	—0.9	66.74	89.06	12.60	13.66	33.84
47.8	15.2	42.9	0.6	2.5	73.50	88.83	14.57	16.35	38.26
46.7	19.7	41.9	2.2	2.0	77.58	88.48	16.79	18.62	43.48
47.3	19.8	41.3	0.9	1.7	77.60	82.68	16.81	18.42	43.16
47.5	21.5	42.4	3.1	5.2	78.0	86.52	16.80	18.21	42.31

Intermediate leading the low by 120 degrees.

TESTS ON THE TRIPLE EXPANSION ENGINE, 9″-16″-24″ × 30″, RUN AS A COMPOUND. — *Concluded.*

Low Pressure Cylinder.											
Initial pressure.	Per cent. cut-off.	Pressure at cut-off.	Pressure at release.	Pressure at compression.	Per cent. of steam in the cylinder at cut-off.	Per cent of steam in the cylinder at release.	M. E. P. crank.	M. E. P. head.	Horse power.	B. T. U. per H. P. per minute. (Actual.)	B. T. U. per H. P. per minute. (Reduced to 26″ vacuum.)
20	21	22	23	24	25	26	27	28	29	30	31
—7.1	40.5	—8.15	—11.3	—12.7	62.93	69.13	3.26	3.62	19.70	409.5	429.9
—3.1	....	—6.1	—11.0	.....	55.98	66.50	4.28	4.26	24.42	399.8	413.2
1.6	....	—2.9	— 9.9	.....	54.03	58.85	6.44	6.51	36.04	386.9	386.9
1.8	....	—3.0	— 9.5	.....	52.85	67.52	6.37	6.41	35.40	383.6	377.1
4.1	43.0	—5.4	— 9.8	—11.7	62.0	69.50	4.78	5.31	28.40	382.8	382.8
—3.4	45.5	—5.6	— 9.18	—11.5	63.77	67.70	5.46	5.79	31.40	373.2	375.0
2.8	....	2.3	9.3	11.6	54.61	62.86	7.09	7.11	39.38	377.0	372.8
3.7	....	—1.0	— 9.2	.....	54.36	63.08	7.17	7.18	39.69	381.6	379.7
1.7	36.5	—1.0	9.1	10.9	63.38	66.54	7.73	7.91	43.10	376.8	370.6
—1.8	50.0	—4.1	— 8.3	11.0	61.27	68.19	6.47	6.77	36.30	376.0	368.0
2.0	50.0	—3.6	— 8.2	11.0	64.43	65.65	6.64	6.72	36.80	377.5	372.1
1.0	....	—4.9	10.16	11.6	78.75	76.69	5.91	6.03	35.12	385.4	382.3
0.12	....	—2.5	—10.2	.....	75.79	75.29	6.57	6.98	38.47	377.7	384.4
—0.19	....	—3.5	10.0	.....	79.97	76.49	6.94	7.23	40.11	358.0	362.2
—0.10	....	—3.4	— 9.0	.....	84.64	85.55	6.87	6.84	38.71	367.6	365.4
1.67	....	—2.6	—10.1	.....	79 61	73.39	7.84	7.92	44.35	360.3	366.1
—0.5	....	—3.0	—10.0	.....	81.45	70.90	7.31	7.60	42.01	362.7	362.7
1.62	....	—2.2	— 9.9	.....	81.05	72.48	7.81	7.98	44.40	358.3	356.2
2.99	....	—1.9	— 9.5	.....	79.63	76.74	8.21	8.35	46.46	358.4	356.4
1.4	....	—2.9	— 9.5	.....	74.70	73.76	7.64	7.92	43.56	354.5	352.6
2.01	....	—2.0	— 9.3	.....	74.39	72.56	7.93	8.69	46.33	352.5	354.1
2.8	....	—1.0	— 8.8	.....	80.42	75.86	9.04	9.52	51.52	345.7	341.1
3.3	....	+0.6	— 8.6	.....	80.56	75.16	9.36	9.62	52.70	339.6	340.9
5.4	....	+1.1	— 7.7	.....	77.61	74.31	9.93	10.27	56.89	352.7	345.7
6.1	....	—1.7	— 7.4	.....	77.59	79.17	10.89	10.72	61.01	348.5	342.0
—2.3	....	—5.1	—11.0	....	89.09	81.73	5.61	5.67	32.16	338.0	332.9
—1.7	....	—4.5	—10.2	.....	86.19	79.90	5.52	5.96	33.59	344.6	337.1
0.9	....	—3.3	—10.0	.....	82.82	73.90	7.49	7.48	42.04	326.6	325.6
1.3	....	—2.4	— 9.2	.....	77.42	76.46	7.89	7.97	44.20	333.9	333.9
1.8	....	—2.0	— 9.3	.....	85.25	76.31	8.34	8.67	47.31	321.9	323.2
3.5	....	—0.6	— 9.6	.....	83.54	67.70	9.25	9.51	52.08	324.9	328.7

TESTS ON THE TRIPLE EXPANSION ENGINE, 9″-16″-24″ × 30″.

Horse Power.	Steam per H. P. per hour.	Steam through cylinders per hour.	Water by Jackets per Hour.			Revolutions per minute.	Boiler pressure. (Gauge.)	Vacuum in condenser. (Inches mercury.)	Barometer.
			High pressure cylinder.	Intermediate pressure cylinder.	Low pressure cylinder.				
1	2	3	4	5	6	7	8	9	10
53.21	17.28	919	....	....	....	85.60	152.8	26.1	29.7
55.73	16.86	931	....	....	....	85.62	153.3	26.1	....
60.6	16.19	981	....	....	....	85.60	152.1	26.1	29.9
69.8	15.80	....	....	....	....	81.66	146.3	19.8	29.7
74.9	15.39	1,148	....	....	....	84.22	152.8	25.9	29.8
85.8	15.12	1,298	....	....	....	83.03	152.0	26.3	....
86.9	15.39	1,338	....	....	....	82 92	152.4	26.09	30.15
87.8	15.26	1,339	....	....	....	82.55	153.0	26.02	30.0
91.1	15.47	1,409	....	....	....	83.32	152.0	25.70	....
99.9	15.54	1,552	....	....	....	82.67	151.9	25.6	30.0
100.5	15.16	1,525	....	....	....	81.78	152.0	25.7	....
102.4	14.95	1,531	....	....	....	82.92	152.5	26.0	29.9
106.0	15.24	1,631	....	....	....	81.52	151.5	26.1	29.9
108.2	14.91	1,613	....	....	....	81.57	152.0	26.0	....
111.2	14.33	1,592	....	....	....	81.40	152 0	26.04	30.1
112.2	15.16	1,693	....	....	....	81.50	151.9	25.9	30.26

High Pressure Cylinder.

Initial pressure.	Per cent. cut-off.	Pressure at cut-off.	Pressure at release.	Pressure at compression.	Per cent. of steam in the cylinder at cut-off.	Per cent. of steam in the cylinder at release.	M. E. P. crank.	M. E. P. head.	Horse power.
11	12	13	14	15	16	17	18	19	20
148.3	8.4	142.9	14.6	15.7	65.0	82.5	38.6	32.7	28.4
148.4	8.3	140.7	12.4	11.8	64.0	77.4	39.3	36.2	30.1
148.0	10.6	141.1	16.2	16.6	68.3	81.4	41.3	38 1	29.6
142.7	14.6	139.8	20.6	18.6	68.9	78.5	46.4	46.8	35.7
149.5	15.8	144.5	24.0	26.4	72.6	83.4	45.7	46.2	36.1
147.4	21.3	137.4	31.0	33.0	74.6	85.0	51.4	46.4	37.8
146.9	21.2	139.7	29.8	29.2	73.8	82.3	54.6	50.3	40.6
148.3	21.0	140.7	30.0	28.4	74.1	82.5	58.8	50.7	42.2
147.6	24.1	142.9	35.8	39.6	76.7	85 8	49.6	53.5	40.2
147.4	29.5	139.5	41.5	47.0	78.5	85.3	49.4	52.0	39.1
146.5	29.1	138.9	40.2	44.2	79.1	85.0	53.8	53.1	40.8
148.5	28.7	142.1	41.5	43.5	80.0	87.0	52 9	57.1	42.6
148.4	30.7	143.1	44.5	47.6	79.4	86.2	57.8	52.3	34.4
147.0	31.8	141.2	44.4	45.1	81 3	86.7	59.7	55.4	43 9
148 0	35.6	137.9	48.9	52.9	82.9	86.2	54.1	54.1	41.8
147.5	33.8	142.1	47.2	51.2	80 8	85.8	56.0	53.9	41.9

Cranks set 120° apart, high leading.

A description of the engine, together with quite an extended series of tests, can be found in Technology Quarterly, Vol. V, No. 3.

TESTS ON THE TRIPLE EXPANSION ENGINE, 9″–16″–24″ × 30″.—*Continued.*

INTERMEDIATE CYLINDER.

Initial pressure.	Per cent. cut-off.	Pressure at cut-off.	Pressure at release.	Pressure at compression.	Per cent. of steam in the cylinder at cut-off.	Per cent. of steam in the cylinder at release.	M. E. P. crank.	M. E. P. head.	Horse power.
21	22	23	24	25	26	27	28	29	30
12.5	15.5	7.4	—7.4	—5.9	48.8	71.40	5.46	5.27	13.9
9.1	22.5	4.9	—6.2	—5.1	54.6	83.96	5.61	5.20	14.0
13.7	17.5	9.4	—6.3	—5.2	53.1	75.31	6.42	5.98	16.0
15.7	25.3	10.0	5.1	3.5	59.1	74.86	7.89	8.42	20.1
22.5	16.5	16.4	—4.7	—2.0	.....	.....	7.56	8.86	20.9
29.5	17.7	24.8	—2.1	—0.08	61.83	81.12	9.74	10.55	25.7
26.9	21.5	20.0	—1.9	—1.1	58.60	81.49	8.89	9.99	23.7
24.5	22.5	18.5	—2.0	—0.5	59.69	80.80	9.22	9.18	23.0
33.3	18.0	26.8	—1.9	1.6	60.72	77.61	10.11	11.79	27.6
42.1	18.0	34.0	1.4	5.4	62.57	85.72	11.28	12.64	30.0
39.7	20.2	52.15	0.8	5.10	70.24	82.95	11.68	13.65	31.3
37.7	19.5	29.7	—0.3	3.2	62.44	79.10	11.62	13.29	31.2
42.5	19.5	36.1	1.1	4.6	65.60	79.85	14.15	13.77	34.4
40.0	21.5	31.3	0.8	4.0	64.64	80.14	13.79	13.60	33.6
47.2	18.3	40.3	1.7	4.5	65.30	80.46	14.8	14.6	36.5
47.1	20.5	38.0	2.7	0.9	66.91	84.43	14.0	14.10	36.0

LOW PRESSURE CYLINDER.

Initial pressure.	Per cent. cut-off.	Pressure at cut-off.	Pressure at release.	Pressure at compression.	Per cent. of steam in the cylinder at cut-off.	Per cent. of steam in the cylinder at release.	M. E. P. crank.	M. E. P. head.	Horse power.	B. T. U. per H. P. per minute. (Actual.)	B. T. U. per H. P. per minute. (Reduced to 26″ vacuum.)
31	32	33	34	35	36	37	38	39	40	41	42
—7.9	26.0	—9.4	—11.7	—12.0	43.5	71.8	1.84	1.88	10.9	317.7	318.0
—6.9	24.5	—8.6	—11.7	—11.8	45.0	74.2	2.12	1.84	11.6	306.5	308.2
—7.2	24.5	—8.1	—11.2	—11.8	47.2	77.5	2.25	2.19	13.0	295.7	296.7
—5.0	48.9	—6.5	—9.7	—9.1	75.7	75.8	2.7	2.32	14.9	278.0	231.4
—5.2	25.9	—7.6	—11.3	—11.6	46.3	64.2	3.03	3.19	18.0	287.1	286.0
—2.4	18.5	—4.9	—11.3	—12.3	43.0	58.6	3.72	4.08	22.3	276.1	277.6
—1.7	20.0	—5.0	—11.0	—11.8	44.1	61.3	3.86	4.11	22.6	280.6	280.8
—2.2	21.5	—5.4	—10.8	—11.8	44.0	64.4	3.91	4.07	22.6	284.1	284.1
—1.8	22.0	—4.3	—10.5	—11.6	49.5	67.4	4.10	4.05	23.3	280.5	278.3
2.3	19.0	—1.9	—10.2	—11.6	48.1	63.7	5.35	5.5	30.8	283.0	280.3
1.5	18.0	—2.2	—10.2	—11.7	46.9	64.4	5.02	5.14	28.5	275.3	273.4
—0.2	21.0	—3.3	—10.9	—11.9	46.7	55.6	5.08	5.27	28.6	271.7	271.7
1.6	21.5	—2.1	—10.6	—11.4	40.3	58.4	5.57	5.57	29.7	278.1	277.6
1.3	22.0	—2.1	—10.3	—11.5	49.5	60.6	5.51	5.43	30.7	271.2	271.2
1.7	21.5	—0.8	—9.7	—11.2	51.6	57.1	6.04	5.74	32.9	274.0	274.0
2.8	20.5	—0.3	—9.6	—11.6	44.1	67.7	6.09	6.15	34.3	274.6	273.9

Tests on a Hancock Inspirator.

Since the time of the tests that were quoted in the *Technology Quarterly*, Vol. VIII, Nos. 1 and 3, new apparatus for testing injectors has been supplied to the laboratories. The injectors are located on the second floor, and draw water from a 6-inch standpipe that runs through the first floor to the basement of the building, giving a lift of from 0 to 25 feet. The water admission to the standpipe is controlled by a balanced valve placed in the supply pipe, this valve being actuated, through a delicate mechanism, by a float in the standpipe itself. The feed supply is taken from the city main until the beginning of the test, when it is drawn from a tank of sufficient capacity for the whole run. This tank is placed on scales, and its weight is taken before and after the test. The delivery water is weighed in barrels. Arrangement has been made for getting an accurate start and finish of both the feed and the delivery. The delivery pressure is kept constant by a back pressure valve placed in the delivery pipe. This valve is connected with the steam pipe, and the delivery pressure is controlled by the working steam pressure. The difference in the weight of the delivery and the feed water is taken as the amount of steam used.

TESTS ON HANCOCK INSPIRATOR NO. 4, C.

Number of test.	Duration. (Minutes.)	Steam pressure.	Delivery pressure.	Barometer.	Lift. (Feet.)	Suction temperature. °F.	Delivery temperature. °F.	Water supplied. (Lbs. per hour.)	Water delivered. (Lbs. per hour.)	Steam used. (Lbs. per hour.)	Water delivered. (Per lb. of steam used.)	Thermal efficiency. (As pump and heater combined.)	Delivery.	Delivery capacity. (Gals. per hour.)
52	30	37.7	49.8	14.6	4.01	87.3	146.8	4,950	5,259	309	17.0	91.8	Max.	642
53	30	39.8	52.9	14.7	3.99	46.9	112.1	3,824	4,079	255	16.0	90.6	Min.	493
57	30	42.7	56.6	14.7	4.00	49.3	113.5	5,326	5,659	333	17.0	95.2	Max.	685
58	30	42.8	58.2	14.7	4.00	46.2	110.3	5,306	5,653	347	16.3	90.5	Max.	684
59	30	43.2	58.4	14.7	4.00	61.3	124.5	5,367	5,691	324	17.6	98.3	Max.	691
61	30	43.4	59.1	14.6	3.99	66.7	131.0	5,282	5,638	356	15.8	90.0	Max.	685
63	30	43.5	56.0	15.0	4.02	72.7	144.3	3,559	3,820	261	14.6	93.4	Min.	466
64	30	43.5	54.2	14.9	4.00	82.2	154.8	3,436	3,693	257	14.4	94.0	Min.	452
65	30	43.5	59.0	14.5	4.02	70.0	133.7	5,194	5,522	328	16.9	95.7	Max.	672
66	30	43.6	57.7	15.0	3.99	85.8	149.2	5,127	5,462	335	16.3	93.6	Max.	667
67	30	43.6	54.4	14.8	4.03	52.3	121.5	3,690	3,951	261	15.1	91.5	Min.	479
68	30	44.1	60.4	14.8	4.00	51.1	116.4	5,368	5,702	334	17.1	97.5	Max.	691

Tests on Pelton Water Wheel.

These tests were made on a 4-foot Pelton wheel made by the Pelton Water Wheel Company, of San Francisco. The water supply was furnished by a Duplex Blake Pump, with which the head on the wheel could be varied from 20 to 230 feet. The head was measured by the use of a 6-inch piezometer located in the supply pipe about two feet back from the wheel nozzle. The pressure at the piezometer was taken either by a mercury column or a pressure gauge. The quantity of water used was measured by passing it over an 18-inch weir. The power developed was consumed by a rope brake. The measurement of the power was made by an Emerson Power Scale placed as a coupling between the brake and the wheel shaft in such a way that the only error introduced was that of the scale itself.

Tests Nos. 1–34 were made at varying heads from 23.9 to 210.6 feet. Tests Nos. 37–62 were made under about the same head, and at varying speeds from 199.5 to 228.4 revolutions per minute. The quantity of water passing the weir was calculated by Francis' formula. The theoretical best velocity of the center of the buckets was taken as one half the velocity of the jet.

TESTS OF PELTON WHEEL.

Number of test.	Date.	Duration. (Minutes.)	Revolutions per minute.	Load on power scale.	Water pressure. (Lbs. per sq. in.)	Head on weir. (Feet.)	Temperature of water. °C.	Total head acting on wheel.	Quantity of water passing weir. (Cu. ft. per second.)	Available work. (Horse power.)	Work at power scale. (Horse power.)	Efficiency. (Per cent.)	Velocity of jet. (Feet per second.)	Velocity of center of buckets.	Theoretical velocity of center of buckets.
	1895.														
1	Oct. 28	30	93.0	83.0	10.3	0.2002	22.4	23.9	0.435	1.18	.936	79.4	42.1	18.0	21.0
2	Oct. 2	29	113.5	126.3	15.0	0.2271	20.0	34.8	0.524	2.06	1.74	84.2	50.7	22.0	25.3
3	Nov. 21	20	115.8	115.6	15.3	0.2269	15.8	35.4	0.523	2.10	1.62	77.2	50.6	22.4	25.3
4	Oct. 3	60	131.5	162.2	20.4	0.2476	21.0	47.3	0.594	3 18	2.58	81.2	57.5	25.5	28.7
6	Oct. 4	30	143.3	205.6	25.2	0.2649	21.1	58.4	0.656	4.34	3.57	82.2	63.5	27.8	31.7
7	Oct. 25	30	148.5	194.0	25.4	0.2689	21.1	58.9	0.670	4.47	3.49	78.0	64.9	28.8	32.4
8	Oct. 9	30	159.5	228.7	29.7	0.2735	20.3	68.8	0.687	5.36	4.42	82.5	66.5	30.9	33.1
10	Oct. 24	30	175.5	257.5	35.6	0.2957	21.0	82.5	0.771	7.20	5.48	76.0	74.6	34.0	37.3
11	Oct. 7	30	174.1	255.5	35.3	0.2958	20.9	81.8	0.771	7.15	5.39	75.4	74.6	33.7	37.3
12	Oct. 22	60	186.7	283.9	40.1	0.3069	20.7	93.0	0.814	8.57	6.43	75.0	78.7	36.2	39.4
13	Oct. 7	30	186.7	282.3	40.2	0.2982	21.2	93.2	0.780	8.23	6.39	77.7	75.5	36.2	37.7
14	Oct. 11	30	196.4	343.8	45.0	0.3216	21.0	104.3	0.871	10.29	8.18	79.6	84.3	38.0	42.1
15	Oct. 8	60	193.7	323.3	45.3	0.3196	21.5	104.8	0.865	10.26	7.59	75.7	83.7	37.5	41.8
16	Oct. 9	60	211.6	344.7	50.1	0.3317	20.7	116.1	0.911	11.98	8.84	73.8	88.2	41.0	44.1
17	Oct. 11	30	203.9	380.1	50.4	0.3312	20.6	116.8	0.909	12.03	9.39	78.1	88.0	39.5	44.0
18	Oct. 23	29	216.5	376.6	55.0	0.3380	21.3	127.5	0.936	13.51	9.88	73.1	90.6	41.9	45.3
19	Oct. 14	30	212.8	380.5	55.1	0.3330	21.8	127.7	0.916	13.24	9.81	74.1	88.6	41.2	44.3
20	Oct. 14	30	230.2	385.2	59.9	0.3397	22.0	138.9	0.943	14.83	10.75	72.4	91.2	44.6	45.6
21	Oct. 21	22	228.1	399.4	59.9	0.3422	20.8	138.9	0.953	15.00	11.04	73.7	92.3	44.2	46.1
22	Oct. 23	60	234.8	429.2	65.3	0.3500	21.0	151.3	0.985	16.87	12.22	74.0	95.3	45.5	47.6
24	Oct. 16	60	243.3	457.1	70.5	0.3551	22.5	163.4	1.006	18.60	13.48	72.4	97.3	47.1	48.7
25	Oct. 18	30	245.8	453.5	70.5	0.3574	22.6	163.4	1.015	18.83	13.51	71.8	98.3	47.6	49.1
26	Nov. 4	30	244.7	455.2	70.4	0.3596	20.0	163.1	1.024	18.92	13.50	71.4	99.1	47.4	49.5
27	Oct. 16	30	253.0	479.8	75.0	0.3621	24.1	173.9	1.035	20.36	14.71	72.2	100.1	49.0	50.1
28	Oct. 21	30	252.8	487.8	75.3	0.3644	21 0	174.4	1.044	20.62	14.95	72.5	101.0	49.0	50.5
29	Oct. 18	30	260.7	515.3	79.8	0.3710	22.5	185.0	1.072	22.45	16.28	72.5	103.7	50.5	51.8
30	Oct. 28	60	259.0	518.9	80 7	0.3728	21.7	187.1	1.079	22.86	16.29	71.2	104.4	50.2	52.2
31	Oct. 29	30	264.8	559.4	85.4	0.3819	18.5	197.8	1.118	25.05	17.96	71.7	108.2	51.3	54.1
32	Oct. 30	30	266.8	556.3	85.2	0.3821	19.5	197.4	1.118	25.02	17.99	72.0	108.2	51.7	54.1
33	Oct. 30	30	270.6	588.7	90.4	0.3893	19.9	209.4	1.149	27.25	19.31	70.9	111.2	52.4	55.6
34	Oct. 31	29	274.7	595.0	90.9	0 3891	20.9	210.6	1.148	27.38	19.81	72.3	111.1	53.2	55.5
37	Nov. 6	30	199.5	414.7	55.42	0.3405	21.1	128.5	0.946	13.77	10.03	72.8	91.6	38.6	45.8
39	Nov. 11	30	215.3	394.3	55.90	0.3419	22.0	129.6	0.952	13.97	10.29	73.6	92.1	41.7	46.1
40	Nov. 8	30	216.6	389.4	56.01	0.3402	23.3	129.9	0.945	13.90	10 22	73.5	91.4	41.9	45.7
41	Nov. 15	30	217.1	387.0	55.91	0.3404	21.0	129.6	0.946	13.88	10.18	73.3	91.5	42.0	45.8
42	Nov. 19	30	217 6	384.6	55.82	0.3397	21.8	129.4	0.943	13 82	10.14	73.4	91.2	42.1	45.6
43	Nov. 18	30	218.1	384 6	55.84	0.3414	20.0	129.4	0.950	13.93	10.17	73.0	91.9	42.2	46.0
44	Nov. 15	30	218.6	380 6	55.88	0.3400	21.0	129.5	0.944	13 85	10.08	72.8	91.4	42.3	45.7
45	Nov. 20	30	218.7	382.1	55.69	0.3387	22.6	129.1	0.939	13.72	10.13	73.8	90.8	42.4	45.4
46	Nov. 22	30	218.9	385.4	55.99	0 3413	17.8	129.7	0.949	13.96	10.23	73.3	91.9	42.4	45.9
47	Nov. 18	30	219.3	382.0	55.76	0.3398	20.8	129.3	0.943	13.81	10.15	73.5	91.3	42.5	45.6
48	Nov. 4	20	220.5	376.4	55.58	0.3406	20.0	128.8	0.947	13.81	10.06	72.8	91.6	42.7	45.8
49	Nov. 8	30	220.5	382 0	56.55	0.3409	22.7	131.1	0.948	14.07	10.21	72.6	91.7	42.7	45.9
50	Nov. 11	30	220.9	381.7	55.74	0.3402	21.9	129.2	0.945	13.83	10.22	73.9	91.4	42.8	45.7
51	Nov. 22	30	221.2	382.0	56.03	0.3391	18.7	129.8	0.940	13.83	10.24	74.0	91.0	42.8	45.5
52	Nov. 13	30	221.3	381.9	55.73	0.3410	21.0	129 2	0.948	13.88	10.24	73.8	91.8	42.9	45.9
53	Nov. 14	30	221.3	380.9	55 77	0.3411	21.4	129.3	0.949	13.89	10.22	73.5	91.8	42.9	45.9
54	Nov. 7	30	221.5	375.4	55.60	0.3399	22.6	128.9	0.944	13.77	10 08	73.1	91.3	42.9	45.7
55	Nov. 12	30	222.0	378.9	55.73	0.3397	21.7	129.2	0.943	13.80	10.20	73.9	91.2	43.0	45.6
56	Nov. 13	30	222.9	381.1	55.96	0.3420	21.8	129.4	0.952	13.96	10.30	73.8	92.2	43.2	46.1
57	Nov. 26	30	223.6	365.3	54.96	0.3379	21.1	127.4	0.935	13.50	9.90	73.3	90.5	43.3	45.3
58	Nov. 6	30	224.3	375.8	55.76	0 3410	21.5	129.3	0.948	13.89	10.22	73.5	91.8	43.4	45.9
59	Nov. 25	30	225.0	374.0	55.76	0.3418	18.5	129.2	0.952	13.93	10.20	73.2	92.1	43.6	46.0
60	Nov. 27	30	225.7	369.2	55.71	0.3393	21.7	129.1	0.941	13.76	10.10	73.4	91.1	43.7	45.5
61	Nov. 25	30	226.8	371.5	55.87	0.3424	20.0	129.5	0.954	14.00	10.21	73.0	92.3	43.9	46.2
62	Nov. 27	30	228.4	364.9	55.60	0.3389	21.2	128.9	0.939	13.72	10.10	73.6	90.9	44.2	45.5

Diameter of nozzle . . . . . 0.1147 feet. Width of weir . . . . . 1.498 feet.
Diameter at piezometer . . . . . 0.5 feet. Circumference of power scale . . 4 feet.
Diameter of wheel through center of buckets, 3.698 feet.

Tests on No. 6 Douglas Hydraulic Ram.

Number of test.	Date.	Duration of test. (Minutes.)	Head on ram. (Feet.)	Discharge head. (Feet.)	Pulses per minute.	Weight of water delivered.	Water fed. (Lbs. per minute.)	Water delivered. (Lbs. per minute.)	Available work. (Foot-pounds per minute.)	Work done. (Foot-pounds per min.)	Efficiency. (Per cent.)	Capacity. (Gals. per hour.
	1896.											
64	Mar. 12	20	4.16	37	50	172	172.2	8.60	716	318	44	62
65	Mar. 19	20	6.5	39	70	307.75	180.9	15.39	1,180	600	51	111
67	Mar. 5	30	5.86	41	62	290	163	9.66	962	396	41	70
69	Feb. 21	30	5.46	46	67	319	166.1	10.30	907	474	52	74
70	Mar. 3	30	5.96	46	66.3	343.5	171.6	11.45	1,020	527	51	88
71	Mar. 2	30	6.0	46	67	365.5	193.5	12.18	1,160	560	48	88
73	Feb. 28	30	6.5	46	73	342	177.9	11.40	1,160	524	45	82
74	Feb. 25	30	5.96	48	70	262	160.7	8 73	958	419	44	63
75	Mar. 20	30	6.0	48	66	264	172	8.80	103	422	41	63
76	Feb. 25	30	6.0	48	70	289	164	9.63	984	462	47	69
77	Mar. 2	20	6.0	48	65	205.7	169	10.29	1,010	494	49	74
78	Feb. 27	30	6.92	48	79	363	160.3	12.10	1,110	581	52	87
79	Feb. 26	30	6.95	51	79	382	207.9	12.73	1,440	649	45	92
80	Mar. 3	30	6.5	53	70	302	172.6	10.07	1,120	534	48	72
82	Feb. 19	30	6.24	57	71	280.2	180.1	9.34	1,120	532	47	67
83	Mar. 10	30	7.12	57	74	306	169.9	10.20	1,210	581	48	73
86	Feb. 20	30	5.98	60	69	222	155.5	7.40	930	444	48	53
87	Feb. 17	30	6.45	60	72	270.5	173.3	9.01	1,120	541	48	65
88	Feb. 21	30	6.7	60	77	274	159.8	9.13	1,070	548	51	66
89	Mar. 6	30	6.58	62	70	204.5	161.3	6.81	1,060	423	40	49
91	Feb. 20	30	6.96	62	75	297.5	175.7	9.91	1,220	615	50	71
92	Feb. 24	30	5.96	69	70	181	154.8	6.03	923	416	45	43
93	Feb. 26	30	6.70	69	75	198.5	154.4	6.61	1,030	457	44	48

Tests on a Compound Marsh Pump, 10″, 16″, and $9\frac{1}{4}$″ × 16″ Stroke.

The steam used by the pump was condensed in a surface condenser and weighed.

The water pumped was measured, first, by means of an underwriter's fire nozzle either $1\frac{1}{8}$″ or 2″ in diameter; then, after leaving the nozzle, by flowing the water over a weir in the second story of the laboratory, and then again by means of a second weir in the basement. The results by the two weirs agreed very closely, but it will be noticed that there is a slight difference between the quantities by the weirs and by the nozzle.

The total head pumped against was found by adding to the difference in level between the water in the suction well and that in the air chamber the head in feet of water due to the air pressure in the air chamber.

Five indicators were used, four on the steam end and one on one end of the water cylinder. Motion for the indicator was gotten through a pantograph attached to a tail-rod screwed into the water piston and running out through the back head of the water cylinder. The length of stroke and number of strokes were obtained by attachments to this same tail-rod.

TESTS ON A COMPOUND MARSH PUMP, 10″, 16″, AND 9¼″ × 16″ STROKE.

Date.	Single strokes per minute.	Length of stroke.	Steam pressure by gauge.	Weight of condensed steam per hour. (Pounds.)	Total head. (Feet.)	M. E. P. Steam Cylinders.				M. E. P. water cylinder.
						High pressure. (Head end.)	High pressure. (Pump end.)	Low pressure. (Head end.	Low pressure. (Pump end.)	
Dec. 17, 1895	26.0	15.14	29.4	379	86.12	18.04	16.98	8.63	7.26	42.75
Dec. 19, 1895	30.3	15.50	39.6	582	116.23	22.92	21.15	9.72	10.33	52.10
Dec. 20, 1895	33.8	15.75	49.3	804	149.81	25.03	23.05	14.76	13.37	69.63
Dec. 20, 1895	34.3	15.73	49.0	850	150.25	24.88	23.19	15.17	13.75	69.48
Jan. 6, 1896	36.2	15.50	49.3	846	160 52	30.11	29.95	12.99	12.98	73.81
Dec. 30, 1895	36.9	15.62	50 5	871	164.89	30.54	28.20	14.60	13.47	75.31
Dec. 30, 1895	37.3	15.63	49.7	870	169.16	29.71	27.87	14.67	13.90	75.86
Dec. 31, 1895	44.2	15.59	59.3	1,118	202.42	33.75	25.82	15.81	14.17	84.27
Jan. 6, 1896	41.9	15.50	59 8	1,081	198.70	35.72	34.45	14.86	16.13	89.34
Dec. 27, 1895	44.7	15.53	59 8	1,231	197.86	33.98	29.75	15.60	14.28	.....
Jan. 1, 1896	46.5	15.50	69.2	1,300	238.95	40.44	37.28	21.48	20.37	109.08
Jan. 2, 1896	50.7	15.60	78.3	1,536	288.60	39.89	36.20	27.82	27.78	125.03

TESTS ON A COMPOUND MARSH PUMP, 10″, 16″, AND 9¼″ × 16″ STROKE.
Continued.

Date.	Horse power steam cylinders.	Horse power water cylinder.	Horse power output.	Efficiency. (Per cent.)	Apparent capacity of pump. (Gallons per minute.	Capacity of pump by hose nozzle. (Gallons per min.)	Capacity of pump by weirs. (Average of two.) (Gallons per min.)	Steam per horse power per hour.	B. T. U. per horse power per minute.	Duty. (Foot-pounds per 1,000,000 B. T. U.)
Dec. 17, 1895	5 84	5.61	4.73	81.0	224.8	218.7	217.3	65.5	1,065	25,080,000
Dec. 19, 1895	8.7[illegible]	8.15	7.42	84.6	268.2	248.9	252.7	66.4	1,083	25,760,000
Dec. 20, 1895	12.5[illegible]	12.34	10.81	86.3	303.9	291.4	288.0	64.3	1,052	27,070,000
Dec. 20, 1895	12.90	12.48	11.06	85.7	307.8	291.4	292.5	65.9	1,079	26,210,000
Jan. 6, 1896	13.89	13.78	12.44	89.5	320.1	306.8	307.0	60.9	997	29,620,000
Dec. 30, 1895	14.73	14.45	12.89	87.5	328.8	310.2	311.2	59.1	968	29,810,000
Dec. 30, 1895	14.92	14.72	13.44	90.0	332 6	315.9	314.7	58.9	964	30,830,000
Dec. 31, 1895	18.39	19.32	17.22	96.2	393.1	346.4	340.0	60 8	998	31,800,000
Jan. 6, 1896	19.02	19.34	17.48	91.9	371.0	.....	350.2	56.8	934	32,480,000
Dec. 27, 1895	19.07	.....	17.29	90.7	396.4	345.5	346.3	58.7	964	31,030,000
Jan. 1, 1896	26.09	26.17	23.31	89.3	411.3	386.6	385.9	49.8	820	35,920,000
Jan. 2, 1896	33.87	32.96	30.74	90.8	451.9	416.9	422.2	45.3	749	40,000,000

INSTRUCTION IN THEORETICAL CHEMISTRY.[1]

By ARTHUR A. NOYES, Ph.D.

The rapid development which the science of general or theoretical chemistry has undergone within the past few years has made imperative radical changes in the systems of instruction in that subject. Ten years ago it was necessary, and unfortunately to-day it is still very common, for text-books and teachers of theoretical chemistry to confine themselves almost exclusively to a discussion of the laws and principles underlying the composition of existing bodies, leaving out of consideration entirely the other great division of chemical science which treats of the changes in the composition of bodies. The older courses of instruction treated very fully the chemical significance of the properties of gases, but were obliged to pass over in silence the more familiar class of substances known as solutions. It is not, however, merely in extent alone that the subject has increased in importance. The recent additions have imparted to it a much more practical character, and have brought it into much closer connection with the experimental work of the ordinary chemist. It will hardly be claimed that a knowledge of the Principles of Avogadro, Dulong and Petit, and Mitscherlich, of the Periodic Law, or of the hypotheses in regard to valence, is of much service in enabling the chemical student to understand the facts met with in his daily experience; but an acquaintance with the laws on which depend the familiar phenomena of neutralization, precipitation, solubility, displacement of one acid or base by another, the behavior of indicators, and the like, is of the greatest practical value to him and of almost constant applicability.

On this account it seems to me urgent to emphasize the importance in courses on general or theoretical chemistry of a detailed and thorough consideration of the recent theories of solution and the constitution of dissolved substances, and of the laws of chemical change and equilibrium. It is not sufficient, as is done in some of the recent text-books on the subject, merely to announce the general principle,

[1] Read at Buffalo before the American Association for the Advancement of Science.

for example, simply to state the fundamental law of chemical statics in the usual formal way, but it is necessary to illustrate it by a great variety of practical applications to known phenomena, until the principle becomes as familiar as the Structure Theory is to the student of organic chemistry. In my opinion, about two thirds of the time available should be devoted to the recently developed portions of the subject. At the Massachusetts Institute of Technology, out of seventy-five hours of classroom work in theoretical chemistry, forty-five are concerned with the phenomena of solutions and of chemical change. Fifteen lectures and recitations are devoted solely to the discussion of applications of the law of chemical equilibrium.

It is unfortunately true that at the present time there is no textbook suitable for an undergraduate student which treats these matters in a satisfactory manner. The teacher can, however, readily obtain the material for such a course from the larger works of Ostwald and Nernst. It may, however, perhaps not be superfluous to enumerate the principal recently developed subjects which ought in my opinion to be considered in an undergraduate college course. They are: The experimental laws of osmotic pressure, vapor pressure, freezing-point lowering and boiling-point raising, and the theoretical relations between them; the abnormal values of these properties in the case of salt solutions, the electrical conductivity and characteristic chemical properties of salt solutions, and the explanation of these phenomena by the Electrolytic Dissociation Theory; the determination of the degree of dissociation of salts from conductivity measurements; the laws of the effect of concentration, temperature, and catalytic influences on the speed of chemical reactions; the law of chemical equilibrium, and the application of it to the phenomena of gaseous and electrolytic dissociation, of solubility effect, of hydrolysis, of the division of a base between two acids, and of indicators; the degree of dissociation and affinity constants of organic acids and bases and other compounds; the effect of temperature on chemical equilibrium; a brief discussion of thermochemical methods and calculations, of the general principles established in the case of the neutralization of acids and bases, of their explanation by the dissociation theory, and of the so-called principle of maximum work; and finally, Faraday's Law of Electrolysis and the relation of electrical and chemical energy in galvanic elements.

It is very desirable that the class-room instruction should be supplemented by laboratory practice. Experience at the Massachusetts

Institute of Technology has shown that a quite satisfactory laboratory course can be given in about thirty hours' time, and, as the apparatus required is not expensive, it would seem practicable to introduce such courses more extensively. The course given at the Institute comprises the following quantitative experiments: Vapor-density determinations by the three methods of Victor Meyer, Hoffmann, and Dumas; molecular-weight determinations with Beckmann's boiling and freezing point apparatus; measurement of the speed of catalysis of methyl acetate by hydrochloric acid; determination of the solubility of one salt in the presence of another; measurements of the electrical conductivity and calculation of the affinity constant of an organic acid; and a thermochemical measurement of the heat of neutralization of sodium hydroxide and hydrochloric acid. It will be seen that almost all these experiments are distinctly chemical in their bearing. Into a more extended course, physico-chemical measurements proper, such as specific gravity, index of refraction, viscosity determinations, and so forth, could be advantageously introduced. In arranging the details of a course like that here described, the teacher will find Ostwald's *Handbook of Physico-Chemical Measurements* of great assistance.

ORIGIN OF PEGMATITE.

By W. O. CROSBY[1] and M. L. FULLER.

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Introduction.

The history of geology is replete with theories of pegmatite, or giant granite — manifold modifications of the agency of water and heat; and this diversity of opinion finds a ready explanation in the fact that in no other class of rocks do we find such a perfect combination of aqueous and igneous characters. Although the intimate association and evident close connection of pegmatite with undoubted plutonic rocks, and their agreement with the latter in composition and relations to the inclosing formations, has led many writers to regard the pegmatite itself as of plutonic igneous origin, it is not long since geologists, from a consideration chiefly of the exceedingly coarse crystallization and frequent comb-structure of the pegmatites, were quite generally united, under the leadership of T. Sterry Hunt, in the conviction that they were true vein rocks, due to the deposition of the various component minerals from solution in open fissures or other preëxisting cavities. Now, however, a decided drift in the opposite direction may again be noted, and the recent literature of the science indicates an approaching consensus of opinion in favor of the

[1] Nearly three years ago (December, 1893) I read a paper on the "Origin of Pegmatite" before the Geological Society of America, a brief abstract of which appeared in the American Geologist for March, 1894. (See, also, Technology Quarterly, 7, 30–31.) In that paper I developed in outline the modification of Lehmann's aqueo-igneous theory of pegmatite, which is more completely elaborated and substantiated in the present contribution; but its publication was deferred, awaiting an opportunity to more thoroughly test the theory in the field. In the summer of 1895 I was able to spend a few days in the pegmatite district of Grafton and Sullivan Counties, in southwestern New Hampshire, and later in the year Mr. Fuller, a student in the Geological Department of the Massachusetts Institute of Technology, undertook, under my direction, a more extended and detailed study of the pegmatites of that region, basing thereon his thesis for graduation the following June. Mr. Fuller's investigation has materially modified and strengthened the aqueo-igneous theory, and hence this joint production.

W. O. Crosby.

association of the pegmatites, in their genetic relations, with plutonic igneous rocks rather than with subterranean aqueous deposits. In fact, the view that pegmatite is in some sense an intrusive rock may be regarded as so well established, through the labors of Lehmann,[1] Brögger,[2] Williams,[3] and others, that the theories of lateral secretion and aqueous deposition are fast becoming of merely historical interest.

This modern view is more acceptable than any of its predecessors mainly because it is less extreme. It is a reaction toward the igneous category, but the pendulum has not swung so far as to wholly exclude the aqueous influences. In short, the new theory is not simply a revival of the old, but it is essentially a combination or compromise — neither igneous nor aqueous, but aqueo-igneous. The modern conception is that in a broad view the pegmatites are igneous rocks, but it is the part which water has played in their formation that has so strongly differentiated them from other igneous types. Although we shall incidentally apply the touchstone of observed facts to all the principal hypotheses, the chief purpose of this paper is a contribution to the aqueo-igneous theory.[4]

The term pegmatite has been employed heretofore in two senses: To designate (1) the macro- and micro-pegmatitic or graphic-granite structure in rocks; (2) a distinct type of coarsely crystalline plutonic rocks, which is characterized only to a slight degree by the pegmatitic or graphic structure, but is especially distinguished, as a rule, by the gigantic scale of its crystallization. It is, of course, in the second sense that the term is employed here. We desire, however, to direct attention at the outset to two prominent facts which appear to us to demand a modification of the definition. First, the pegmatites have a wide range in composition, from the most highly acidic of all rocks (pure quartz) to ultra-basic varieties, giant granite being an appropriate trivial name only for some of the more acid forms. Second, the differences between the pegmatites and the more normal plutonic rocks are textural to a much greater degree

[1] Ueber die Entstehung der alt krystallinischen Schiefergesteine, 1884, p. 24 *et seq.*

[2] Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit und Nephelinsyenite, 1. Theil, pp. 215–225. For translation, by N. N. Evans, see Canadian Record of Science, 6, 33–46 and 61–71.

[3] "Origin of the Maryland Pegmatites." Fifteenth Annual Report United States Geological Survey, pp. 675–684.

[4] The contributions of Brögger and Williams, already referred to, are replete with references, and render citations of the earlier literature unnecessary here.

than mineralogical or chemical. In other words, since the classification is based primarily upon composition (the result of magmatic differentiation), pegmatite should be regarded, not as a distinct species or family of rocks, but rather as a possible textural phase of all, or nearly all, the plutonic rocks; and we may in general say of any plutonic rock that it may be cryptocrystalline, microcrystalline, macrocrystalline, or pegmatitic. Our problem is, then, to account for the pegmatitic phase of the plutonic rocks. While there can be little or no doubt that the acid and basic pegmatites have had a common origin, every student of geology knows that the acid types have been far more generally and extensively observed and exploited, and hence more fully and satisfactorily described, and our own field studies, as already indicated, have been limited chiefly to this class. The conclusions stated in the following pages are to be understood, therefore, as applying especially to the acid pegmatites.

Characters of the Acid Pegmatites.

A complete description of the acid pegmatites is not intended here, but simply an enumeration of the chief features which any satisfactory theory of their origin must explain.

Composition. — The acid pegmatites, like the corresponding normal plutonic rocks, consist of anhydrous silicate species, and usually more or less of free acid (quartz) and traces of free bases (iron oxides, cassiterite, etc.), apatite being, perhaps, the most conspicuous exception, although the complete list of the pegmatite minerals includes also titanite and various niobates, tantalates, and tungstates. The great disparity as regards abundance makes possible a quite sharp distinction between the so-called principal or essential, and the rarer or accessory, species. The essential species include quartz; the acid feldspars — orthoclase, oligoclase, albite, and microcline — the last two being especially characteristic; and the more acid micas, including muscovite and lepidolite and, less characteristically, biotite. The accessory minerals are more numerous, in some cases more distinctive, and especially remarkable for the large proportion of rare species or species that are rare or wholly wanting in all other rocks. A single mica mine in New Hampshire (the Ruggles Mine in Grafton) is said to have afforded sixty-one minerals, and it is undoubtedly true that the list of known silicate species is considerably longer than it

would be if these natural cabinets, or storehouses of fine minerals, had never been studied.

The quartz of pegmatite, as of ordinary granite, is especially characterized by numerous inclusions of water and carbon dioxide. The proportion of carbon dioxide to water has been proved to be so high in some cases — for example, nearly 1 to 1 in the quartz of the Branchville, Connecticut, pegmatite — as to indicate that the crystallization took place under enormous pressure.[1]

Our observations abundantly confirm Williams' statement[2] that the most typical pegmatites are intimately associated with, and pass gradually into, bodies of pure quartz and ordinary quartz veins. But we cannot agree with this writer in drawing across this undoubted gradation an arbitrary line of demarcation as regards origin. On the contrary, we feel that the true theory of pegmatite must recognize this obvious relationship to quartz veins, by making of the latter a possible end-product of the same great process of differentiation which yields the former. In other words, some quartz veins are on the same road that lead to pegmatite, but a little farther along, at the end of the road. On the west side of Narragansett Bay, opposite Conanicut Island, there is, in the cliffs known as the Bonnet and Packard Rocks, a series of mica schists backed by normal granite and traversed by numerous very typical veins of pegmatite 5 to 50 feet wide. A mile to the eastward, on Dutch Island, the veins in the schist are quartz with some feldspar but no mica; while on the west shore of Conanicut Island, so far as observed, they are quartz alone. Van Hise has noted a similar gradation in the character of the pegmatite veins intersecting the schists which envelop the granite core or batholite of the Black Hills, the veins changing gradually from typical pegmatite near the granite to ordinary quartz veins at a moderate distance. (*16th Annual Report United States Geological Survey*, Part. I, p. 688.)

Relations of Composition to the Inclosing Rocks. — Broadly speaking, the pegmatites are independent of the wall rock in composition. In New Hampshire we have found pegmatites of strikingly uniform composition traversing in succession and without sensible change a whole series of granites, gneisses, and schists of the most diverse character. Brögger and Williams have specially noted this indiffer-

[1] A. W. Wright. American Journal Science, March, 1881.

[2] United States Geological Survey. Fifteenth Annual Report, pp. 678 and 679.

ence of the pegmatites to the character of the inclosing formations. The former[1] cites as examples the acid pegmatites of Hitterö, which cut a very basic (labradorite and anorthite) rock, and those of Rudemyr cutting Silurian schists and limestones, and the latter[2] speaks of the acid pegmatites of Maryland as occurring in gabbro and peridotite and extending from gneiss into limestone without sensible change.

The one important exception to this principle is found in the fact which lies at the foundation of the modern theory of pegmatite, viz., that in every pegmatite district there is one normal plutonic rock of essentially similar but slightly less acid composition, with which the pegmatite is most intimately associated, into which it may often be traced, and from which it has evidently been derived. That is, the pegmatites are contrasted with the inclosing formations in all cases except where they traverse the plutonic mass of which they are the most highly differentiated phase or end-product. Brögger and Williams lay much stress upon this fact and cite abundant illustrations of it, noting especially that the pegmatite is more acid than the parent mass. Williams says of the pegmatite dikes of Maryland, "They agree essentially in chemical and mineral composition with the granite masses whose igneous origin is well established, although they are in the main somewhat more acid than these, and their size and abundance are directly proportioned to their nearness to some eruptive granite mass. At many localities they can be seen to decrease steadily both in number and size as they recede from such a granitic boundary." The more acid character of pegmatite than of granite is seen in the fact that among the micas biotite largely predominates in granite, and is the exception in pegmatite.

The parent plutonics of the pegmatites which we have studied in New Hampshire are the Concord granite, and the Montalban gneiss, the latter seeming to be merely a more gneissoid phase of the former. These two granitic types, it may be added, are readily proved by the field evidence to be the youngest and most acidic of the entire granitic series of the region, the facts pointing very plainly to a progressive chemical differentiation of a vast body of magma during a long period, with, at the end, a marked textural differentiation. In New

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[1] Canadian Record of Science, 6, 36 and 37.

[2] U. S. Geol. Survey, Ann. Report, 15, 683.

Hampshire we have not found the pegmatite so abundant in the Concord granite or any plutonic formation as in the fibrolite and other schists, which are easily proved to antedate all these igneous rocks. This is due in part, probably, to the fissile and flexible character of the schists, by virtue of which they offer an easier passage to intrusives than do the more massive formations; and in part, no doubt, to the relative readiness with which they are dissolved or melted away by the invading magma. It may be added that in the schists, as in the gneisses and granites, the amount of pegmatite is, in general, inversely proportional to the distance from the Concord granite.

It is a reasonable expectation that the absorption of great bodies of schist should affect the composition of the pegmatite. In fact Geikie says (*Text-Book of Geology*, p. 302), igneous rocks dissolve or eat away the inclosing formations, and in consequence vary considerably in composition from place to place. The schists are poor in alkalies, being composed chiefly of silica and alumina; and their absorption by the pegmatite magma would obviously tend to make the pegmatite richer in quartz and muscovite, as the following comparison of the alkaline silicates shows, the formation of a pure aluminum silicate being impossible in the presence of alkalies.

Orthoclase, SiO_2, 64.7; Al_2O_3, 18.4; alkalies, 16.9
Muscovite, SiO_2, 46.5; Al_2O_3, 33.9; alkalies, 10.0.

This is in harmony with our observation that the mica mines of New Hampshire, and so far as we are able to learn of other regions, are chiefly in the schist series, and we believe that in general the pegmatite is more micaceous in the schists than in the granite. It may be that we have here an explanation of greisen — that rather anomalous aggregate of quartz and mica. Lepidolite has been noted as a specially characteristic feature of pegmatite, and the fact that it also occurs in greisen is certainly suggestive of the genetic relationship of the two rocks. We also venture the suggestion that perhaps pegmatite rich in tourmaline, and tourmaline or schorl rock (tourmaline and quartz) may be explained in the same way, tourmaline representing a still greater dearth of alkalies — 2 to 4 per cent.

Although this close agreement in composition between pegmatite and its parent plutonics certainly holds for the principal component minerals, the two types seem to be contrasted as regards their rarer or accessory constituents, pegmatite being much richer in these than

granite. G. vom Rath, in his account of the celebrated pegmatite veins of Elba,[1] says that the "tourmaline, beryl, lithia mica, etc., are foreign to normal granite," and that "these veins, on account of their wealth in rare and peculiar minerals, which for the most part are wanting in the wall-rocks, necessitates the assumption of a special mode of formation quite different to that assumed for the wall-rock." That the rare species are a more conspicuous feature of pegmatite than of granite is obvious, but that they are absolutely much more abundant when large volumes of rock are compared, has certainly not been proved, and is at least doubtful. The same slow process which builds the giant crystals of spodumene, beryl, etc., must tend to gather the materials from a large volume of magma. In other words, although in the number and variety of the accessory minerals the pegmatite veins far exceed the known species of the normal granites, we have good reason for believing that in these rarer or accessory as well as the more abundant or principal minerals, the two types are essentially similar if not almost identical, or at least that bulk analyses would show a substantial agreement in chemical composition. Substances which are so sparingly and thinly diffused in the normal granites as to be almost or quite inappreciable are, if not actually concentrated in the pegmatite, developed in a more concrete and tangible form.

Texture. (*Crystallization.*)—Undoubtedly the most distinctive and striking feature of the pegmatites is the crystalline structure, which is, in general, on a remarkably coarse or gigantic scale, and unparalleled among the sedimentary and normal igneous rocks. Well formed crystals of feldspar and mica, and even of such rare accessories as beryl and spodumene, from 6 inches to a foot or more in diameter, are normal occurrences. In fact, as regards the size, perfection, beauty, and variety of the specimens which they afford, the pegmatites are, more than all other rock formations taken together, the great repositories of crystallized silicates, as every good mineral cabinet testifies; and it is thus easy to understand why the pegmatite veins are objects of the highest interest to students of mineralogy. An examination of the mineral localities of New England and Canada, not to take a broader view, would undoubtedly show that a very large majority of the more interesting occurrences are in acid or basic pegmatites.

[1] Die Insel Elba (Geogn.-min. Fragmente aus Italien, VIII) in Zeitschr. d. d. geol. Ges., 1870, 22, 649.

The maximum crystallization is indicated by the great beryls from a foot to a yard in diameter in the mica mines of New Hampshire, the largest known example of which is in the Museum of the Boston Society of Natural History, and the gigantic spodumenes from 10 to over 30 feet in length, and from a foot to a yard in diameter, in the tin mines of the Black Hills. In the pegmatites of New Hampshire we have frequently observed feldspars ten feet or more in length, and one crystal in the American Mine in Groton measured fully 20 feet; while Brögger mentions[1] feldspar individuals more than 10 meters (nearly 33 feet) in length. It is, of course, by virtue of the large scale on which the crystallization has taken place that the pegmatite veins are not quarried for granite, but rather to obtain mica, feldspar, and quartz for commercial purposes, these and many rarer species for mineral cabinets, and tourmaline and other gems.

Brögger[2] also points out that coarseness of crystallization alone does not "condition the pegmatitic nature of the veins, nor is even necessarily present in order to justify the appellation pegmatitic. It is the habitus as a whole which determines this." Nevertheless, this giant granite texture is very constant, and clearly, as already stated, the most distinctive and essential character of pegmatite. One fact to be specially noted is that the coarseness of texture or scale of crystallization is not proportional to the size of the masses, for dikes and bosses hundreds of feet wide may be finer grained than those 5 to 20 feet wide. Thus the great boss of pegmatite forming Mt. Tug, in Orange, 500 feet wide and 1,500 feet long, is relatively fine-grained, while, as marking the other extreme, we recall a vein in Groton less than 2 feet wide containing stout crystals of feldspar 20 inches broad.

Next in order stands the irregularity of both the mineral composition and texture. The normal plutonics are remarkably even grained and uniform mixtures of the component minerals; but in the pegmatites the principle of segregation has evidently had almost unrestricted play, and irregularity is the rule. It is difficult to do justice to this somewhat indefinite character in words; but every one who has observed pegmatites in the field will fully appreciate it. As noted by Brögger,[3] the finer grained portions of the pegmatite often become eugranitic and indistinguishable from the parent plutonic.

[1] Canadian Record of Science, 6, 67.

[2] Ibid., 69 and 70.

[3] Ibid., 6, 64.

The order of crystallization of the various minerals in pegmatite is the same as for the normal plutonics — tourmaline (and other basic species), biotite, muscovite, basic feldspar, acid feldspar, and quartz — and equally constant, (Figure 1). Pegmatite agrees with the normal plutonics, also, in the approximately idiomorphic character of the earlier crystallizations, the quartz being always allotriomorphic. In the vugs and pockets of the pegmatite veins, however, the order of crystallization is reversed, except for tourmaline and other ultra-basic species, and the quartz is idiomorphic. This reverse order is well shown in the abundant association of albite and muscovite in the pockets of the pegmatite veins of Groton, Orange, Grafton, and other towns. The albite occurs as distinct tabular crystals (clevelandite) projecting into the cavity; and implanted on the albites are the muscovites. Notwithstanding the lateness of its crystallization, the quartz not infrequently forms immense vitreous masses (Figure 2), and these often pass into veins of quartz, or quartz and accessory feldspar, intersecting the normal pegmatite as well as the country rock (Figure 3), thus testifying clearly to the extremely acid character of the magma residuum.

Rosenbusch has sagaciously correlated the pockets and druses with the miarolitic structure of the normal plutonics — a feature of like significance, but developed, like the crystallization, on a grand scale. Evidence of contemporaneous crystallization is abundant in all the larger masses, the crystallization of the later species having begun before that of the earlier ceased. It is sufficient to merely mention the unique example of this which we have in graphic granite. A tendency to this regular intergrowth of quartz and feldspar is frequently manifested; but it rather rarely attains to its ideal development. The perthitic intergrowth of the feldspars has, apparently, a like significance. When the earlier crystallizations assume slender, prismatic forms, as is notably the case with tourmaline, the subsequent hardening and crystallization of the silica (quartz) involves not only the inclosure, but also the distortion and breaking, of the guest crystals.

Structure. — It is among the varied structural phases of pegmatite that aqueous and igneous characters — the features of veins and the features of dikes — are most perfectly blended. The pegmatite masses, like true dikes, are frequently fine-grained next the wall, becoming rapidly coarser toward the center. Where the inclosing formation is the parent plutonic, the fine-grained portion, as previously

FIG. 1. TOURMALINE IN PEGMATITE ON AND NEAR THE WALL-ROCK (MICA SCHIST) CHANDLER'S MILLS, N. H.

FIG. 2. MASS OF QUARTZ IN PEGMATITE. OSGOOD'S LEDGE, ACWORTH, N. H.

noted, sometimes becomes eugranitic and grades into the wall-rock without any line of demarcation. This contact zone of the pegmatite masses is, perhaps, the most usual phase of the banded structure to which the advocates of the aqueous theory attach so much importance. Brögger says,[1] "The zonal structure, when any such is present, which, however, is generally not the case, usually makes itself evident only in a finer-grained condition of the vein boundaries, and sometimes (especially in the case of granitic pegmatite veins) in a zone with graphic structure next the fine-grained eugranitic marginal zone, upon which there frequently follows (especially in acid granitic pegmatite veins) in the middle of the vein a tremendous size of grain, here often with special enrichment in rarer minerals and also (particularly in acid veins) not seldom with open or distinctly drusy cavities filled with peculiar mineral deposits." All this accords with our observations; but, besides this pseudo-banding, there is a true vein-banding closely akin to that of undoubted aqueous formations. This, however, is of rather rare occurrence; and, according to our observations, mostly confined to the narrow, linear, crack-filling veins, such as abound in the Concord granite. We are unable to agree with Brögger that this banding is always distinct from that of true veins, "inasmuch as the outer zones pass continuously into the inner." We will only cite a single instance; but this appears to be typical. In the Museum of the Boston Society of Natural History is a complete cross-section specimen from a well-defined linear vein of pegmatite in Chesterfield, Mass. The width of the vein is six to seven inches; and it is made up of two sharply defined and symmetrical bands or layers of albite (clevelandite), with the tabular crystals set edgewise to the walls, and a median band of smoky quartz; while springing directly from either wall and penetrating both the albite and quartz are numerous slender prisms of green and red tourmaline. The order of crystallization is clearly marked; and it is very obvious that in this instance the successive periods or generations did not overlap. The minerals were deposited strictly in succession, although, for that matter, a certain amount of contemporaneous deposition is common enough in true veins.

The disposition of the tourmalines noted above is highly characteristic; and may be observed in many massive or unbanded veins;

[1] Canadian Record of Science, 6, 66.

showing that this comb-structure and a distinct banding are not necessarily correlative, although they are undoubtedly of like significance, testifying with equal distinctness to successive crystallization. The comb-structure is also observable in the disposition of other prismatic minerals and of such tabular species as mica and albite, which are almost invariably set edgewise or perpendicular to the walls in veins of regular form and structure.

Although occurring but sparingly, vugs or pockets and druses are to be regarded as highly characteristic and significant structural features of pegmatite—interesting and entirely normal possibilities of the pegmatite process. In the New Hampshire pegmatites we have found them almost exclusively in the larger veins and masses; and some of these are of large dimensions, as may be inferred from the fact that a pocket in the Palermo Mine, in Groton, has afforded a well-formed crystal of quartz about a yard in diameter. These great pockets are wholly irregular in form, and seem to have no definite position in the vein, except that they are never peripheral. In other districts, pockets in narrow and distinctly linear veins have been observed. These are flatly lenticular in form and, except mineralogically, in no wise distinguishable from the pockets of ordinary mineral veins.

Inclosed fragments of the wall-rock are an exceedingly common and characteristic feature of pegmatite; and the inclusions are, almost without exception, as so commonly in the normal plutonic rocks, in perfect agreement in position and orientation of the lamination or other structural features with the adjacent wall-rock. This peculiarity of the inclusions, although not absolutely incompatible with the aqueous theory of pegmatite, certainly accords best with the plutonic igneous theory. In two instances only have we observed inclusions that appeared to be foreign to the immediately adjacent part of the wall; viz., in small veins near the Palermo Mica Mine of North Groton and in the southern part of Grafton. In both cases the foreign inclusions are of the dark hornblendic Bethlehem gneiss, while the wall-rock is fibrolite schist in the first instance and the coarse porphyritic granite in the second.

In many cases the inclusions, especially of schist, have an exceedingly frayed-out and skeleton-like appearance, suggesting a differential solvent action and shredding rather than mere mechanical breaking or cracking. The wall itself is often similarly affected, as

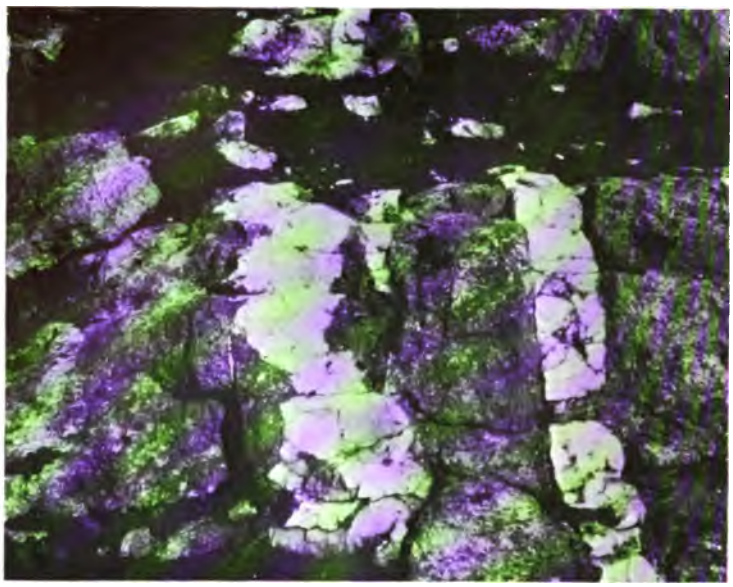

FIG. 3. VEINS OF QUARTZ IN PEGMATITE.
OSGOOD'S LEDGE, ACWORTH, N. H.

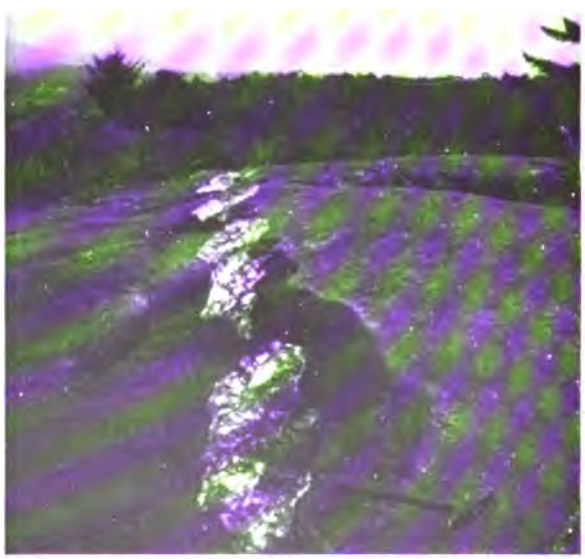

FIG. 5. LENSES OF PEGMATITE IN WINNEPESAUKEE GNEISS.
HONEY BROOK LEDGES, ACWORTH, N. H.

well as more or less distinctly impregnated with tourmaline and other minerals of the first crystallization. This is perhaps the most significant of all the contact phenomena coming under our notice.

We have not observed any clear examples of the centric or spheroidal structure described by L. von Buch and others, and so strongly insisted upon by Brögger; nor has the rare fluidal structure cited by Brögger[1] come under our notice. But we have noted one fact which very plainly suggests motion in the mass during the crystallization of the pegmatite. In a small vein in the Winnepesaukee gneiss north of Honey Brook, in Acworth, the tourmalines, which extend about two-thirds of the way across the fissure, are for a distance of many feet tilted uniformly from the perpendicular to the wall about thirty degrees. This tilting is real and cannot be explained by any irregularity of the walls.

External forms and formal relations to inclosing rocks. — With pegmatite, as with pretty much all subterranean formations, form is less distinctive and significant than structure or composition; and the morphologic argument is rather evenly divided between the rival theories—aqueous and igneous. In general, the occurrences are dike-like in form; but they may with equal propriety be described as vein-like.

No doubt the spaces or cavities occupied by the pegmatites are chiefly mechanical in origin — spaces of discission; and they must, therefore, be conditioned by the structure of the inclosing rocks and the nature of the disrupting force. The more regular masses may be described as rectangular (Figure 4), wall-like (vertical sheets), lenticular (Figure 5), or tabular (horizontal sheets); but a very large proportion of the occurrences are too irregular to come under either of these terms (Figure 6). They very commonly conform closely with the structure planes of the schistose rocks (interbedded veins); but they also intersect the bedding planes or lamination at all angles; and may in general be assumed to follow lines of least resistance to the disrupting force.

We were surprised to find that the cavities occupied by the pegmatite are, on the whole, more crack-like (parallel sides, definite angles, and general linear character) and more plainly suggest a mechanical or disrupting force in the massive rocks than in the bedded and

[1] Canadian Record of Science, 6, 64 and 65.

schistose rocks; and for many of the pegmatite masses in the schists the mechanical explanation is entirely inadmissible, the pegmatite having evidently made room for itself by dissolving and absorbing considerable volumes of schist — spaces of dissolution. We have a magnificent example in the great body of pegmatite at the Ruggles Mica Mine, in Grafton. It has great breadth in the vertical schists, and the schists, without change of dip, completely cover the pegmatite, the bedding planes ending downwards squarely against the approxi-

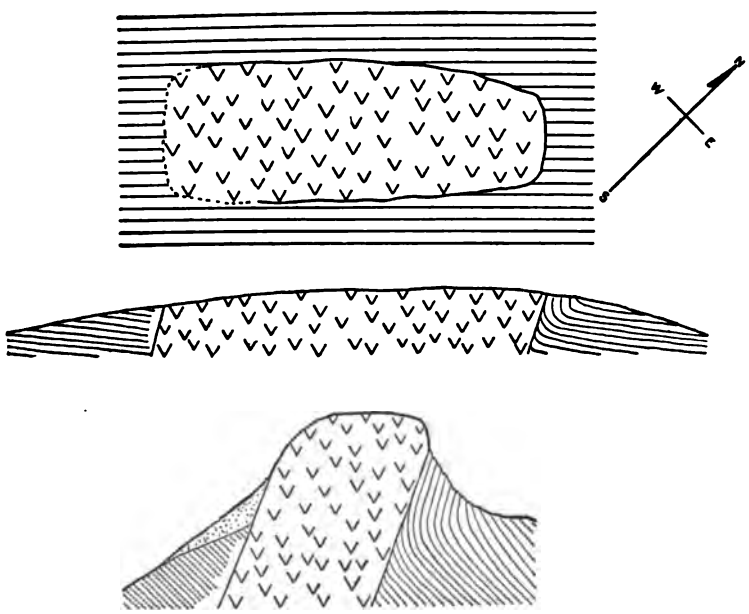

FIG. 4. — PLAN AND SECTIONS OF THE GREAT VEIN OF PEGMATITE FORMING OSGOOD'S LEDGE, ACWORTH, N. H. ONE INCH = 400 FEET.

mately flat upper surface of the great boss or stock of pegmatite (Figure 7). Evidently, no theory of pegmatite can be regarded as adequate which fails to take account of both of these diverse causes of the cavities — rifting and solution.[1] Still a third cause must be invoked where the pegmatite is inclosed in, and blends with, the parent plutonic rock.

[1] According to the observations of Delesse, volcanic rocks, when reduced to a molten condition, attack briskly the sides of the Hessian crucibles in which they are contained and even eat through them.

FIG. 6. IRREGULAR VEIN OF PEGMATITE IN WINNEPESAUKEE GNEISS.
HONEY BROOK LEDGES, ACWORTH, N. H.

FIG. 8. VEINS OF QUARTZ AND PEGMATITE IN MICA SCHIST.
CROYDON MT., GRANTHAM, N. H.

Although, as indicated, certain more or less definite terms may be applied to the pegmatite masses, the great majority are decidedly irregular and indefinite in form. In every instance the pegmatite is clearly younger than the foliation of the inclosing rocks. The masses vary in size from almost miscroscopic veinlets, which, as Williams[1] has pointed out, show a high degree of liquidity in the original magma, up to bosses or dikes 500 feet or more, in width. So far as we have observed, the largest masses show a tendency to the rectangular type. These include Mt. Tug, Orange, 500 x 1,500 feet; Osgood's Ledge, Acworth, 175 x 700 feet; Palermo Mine, Groton, 200 x 500 feet.

Some of the rectangular forms are probably blunt lenses. The lenticular form is also very typically developed in some of the larger masses, such as the great veins on Crystal Mountain, Lempster, 80 x 300 feet, and Trow's Hill, Sunapee, 50 x 400 feet. We have already noted that the pegmatite dikes become smaller and fewer away from the parent mass of granite. The minor lenticular veins, isolated lenses or eyes, conforming with the foliation of the schists, present an interesting problem as to the source and mode of introduction of the component minerals (Figure 8).

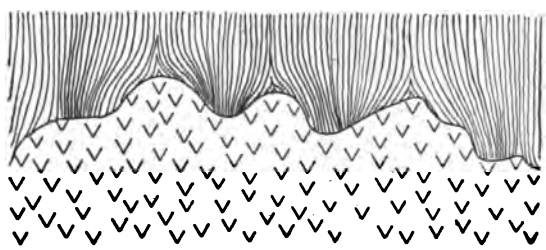

FIG. 7 — VERTICAL SECTION OF PEGMATITE AND OVERLYING SCHIST. RUGGLES MINE, GRAFTON, N. H.

AQUEOUS THEORIES.

All subterranean aqueous deposits may be referred to three classes: veins, impregnations, and substitution deposits.[2] The second and third classes may safely be set aside at once as incapable of throwing any light upon the origin of pegmatite; unless, indeed, the solution and absorption of a body of schist by molten magma be regarded as a mode of substitution. It is sufficient for our present purpose to recognize the two main types of veins: (1) endogenous veins formed chiefly by ascending solutions in fissures or cavities; (2) exogenous veins,

[1] U. S. Geol. Survey, Annual Report, 15, 681.

[2] Technology Quarterly, 7, 27–48.

formed chiefly by lateral secretion in rocks devoid of sensible fissures or cavities. The characters of the endogenous or fissure veins are well known, the most significant, perhaps, being the banding or crustification, comb-structure, and pockets. The exogenous or segregation veins are especially characterized by their homogeneity of composition and structure and the absence of pockets.

The view that pegmatite masses are, in origin, akin to mineral veins, originally proposed by Saussure, has in recent years been most positively asserted and strongly defended by T. Sterry Hunt. He held[1] that the pegmatites have been formed by the successive deposition of mineral matter from solution, usually in open fissures; and in the development of the genetic hypothesis[2] he states that "the gneisses and bedded granites are to granitic veins (pegmatite) what beds of chemically deposited limestone and travertine are to calcareous veins."

In reviewing the characters of pegmatite, a goodly proportion are found to be common to one or the other of the two types of veins noted above; and to admit of explanation, therefore, by the purely aqueous theories. Among these are the following: (1) rare minerals; (2) coarse crystallization; (3) banding and comb-structure, with tourmalines, etc., normal to the walls; (4) inclusions of water in quartz, etc.; (5) pockets and druses. On the other hand, vein formation does not satisfactorily explain: (1) the order of crystallization, except in pockets; (2) completely idiomorphic crystals; (3) the graphic structure; (4) the finer crystallization next the walls, at least this is more suggestive of igneous contacts; (5) broken tourmalines, etc.; (6) inclined tourmalines; (7) inclusions of carbon dioxide; (8) immense size of many of the veins; (9) evidence of solution of the walls; (10) orientation of inclusions. The characters of the first list point unequivocally to the intervention of water in the formation of pegmatite; while those of the second list demand with equal distinctness important modification of the aqueous process.

Igneous Theories.

One of the earliest, and at the same time one of the clearest and most satisfactory, statements of the igneous theory of pegmatite is

[1] Notes on Granitic Rocks, Amer. Jour. Sci., III, 2, 89.

[2] Mineral Physiology and Physiography, 1886, 133.

that by Charpentier (1823). He held that the pegmatites are "injections of granitic material, which, originating in the still fluid granite, deep down, was pressed into the cracks of the already solidified granite above — afterbirths, as it were, of the same granitic formation in the district of which they occur."

This idea was accepted by De la Beche, Bronn, Fournet, Durocher, and Angelot; and Naumann[1] regarded it as the most probable theory.

Brögger quotes Charpentier's view approvingly; and his own paper, one of the most notable of the later contributions to the literature of pegmatite, is essentially a defense and farther development of this early igneous theory. He reviews critically the views of other writers, and argues strongly in favor of magmatic solidification, holding that it affords satisfactory explanations of the chief facts of composition, texture, structure, and relations to the inclosing formations.

That water plays a more or less essential part in the formation of igneous magmas, at least those of acid character, is now so generally conceded that it would be idle to advance arguments against the view that pegmatite is the product of dry fusion. In fact it would probably be difficult to prove that any of the so-called igneous rocks, have resulted from strictly anhydrous processes. The real question is, then, can acid pegmatites be regarded as the direct product of such a slightly aqueo-igneous fusion or magma as yields the normal granites? It appears to the writers that a sufficient answer to this question is to be found in the characters of granite — a fine and even-grained rock of remarkably uniform composition and devoid of pockets. This absolute lack of agreement in the fundamental characters seems to render a more detailed comparison superfluous. It is thus obvious that the igneous theory also, although accounting satisfactorily for the order of crystallization in pegmatite, broken crystals of tourmaline and beryl, parallel orientation of inclusions, etc., requires important modification, and especially a larger intervention of water; for it does not appear that the variation of any other factor, such as pressure or temperature, would meet the necessities of the case.

Brögger, however, among recent writers, seems disposed to minimize the influence of water; and in the differentiation of pegmatite from normal granite to allow it practically no part whatever. He

[1] Lehrbuch der Geognosie, 2d. Ed., 2, 232 (1858).

says[1] "the principal requirement for the solidification of deep-seated magmas to holocrystalline plutonic rocks seems, therefore, to consist in a sufficiently slow cooling of the water-bearing magma, under a pressure of superimposed matter great enough to prevent the water separated out by crystallization from freely escaping to the surface, and compelling it by a pressure exerted from above to pass into the wall-rock (contact metamorphism)." Although so clearly recognizing the presence of water, and using it to account for certain contact phenomena, he does not, apparently, regard it as in any way essential to magmatic differentiation, either chemical or textural, but treats the magma, virtually, as if it were anhydrous throughout its entire history; and yet he repeatedly invokes the aid of certain "agents mineralisateurs," which are nowhere more explicitly designated or described. His non-utilization of the water in the magma, obliges him to refer the gigantic crystallization and irregular composition so characteristic of pegmatite wholly to the slowness with which it has cooled and solidified. He says[2] "both when they (the pegmatites) occur in the main mass of the allied eruptive rock (parent plutonic), and when they occur in the neighborhood — and one of the two is always the case — we may assume that the rock surrounding the vein-stone (pegmatite) was first heated to a high temperature and that, therefore, the cooling must have taken place unusually slowly and uniformly; and upon this fact primarily the largeness of the grains may be explained."

This explanation of these extremely important characters, which no theory of pegmatite can ignore, appears to us singularly inadequate, in view of the following considerations: (1) The surrounding rocks must always be cooler than the great body of granitic magma by which they are heated. (2) The coarsest pegmatite is often in narrow dikes thousands of feet if not miles distant from the border of the plutonic mass in which it originated. (3) If, as Brögger insists and we believe, pegmatite is the end-product or final crystallization of the original granite magma, we are, to paraphrase his criticism of Lehmann (p. 43) led to the remarkable result that a body of magma solidifying as the result of cooling has a higher temperature and therefore crystallizes more slowly and coarsely in the later than

[1] *l. c.*, 45.

[2] *l. c.*, 67.

in the earlier stages of the process. (4) Brögger holds that the most typical pegmatite may be, and in special instances cited by him must have been, formed at very moderate depths below the earth's surface —a few hundred feet to two or three thousand feet. How, under these conditions, the vast body of granite magma at greater depths and cooling far more slowly escaped conversion into pegmatite is a mystery which he nowhere offers to explain.

But he goes on to say[1], "That this explanation of the coarse grain and of the imperfect zonal structure of many pegmatite veins is correct, is rendered probable in the highest degree by the frequent occurrence of pegmatitic structure in those portions of rock bordering on the open drusy cavities of many massive granites. Interpret these as analogous to the formation of the pegmatite veins themselves, in the following way: First, on account of the contraction due to crystallization of the rock already for the most part solidified, there were formed crystal-free *lumina* (microlitic structure on a large scale); the mixture of magma and crystals so formed, which must have constituted a somewhat solid rock, inclosing the lumina, was however completely permeated by the magma, and with this these crystal-free spaces would naturally have been filled. By continued cooling this magma, beginning at the walls, also crystallized out slowly and uninterruptedly, often mixed with minerals which had been formed by special 'agents mineralisateurs;' the conditions of such crystallization, proceeding from the walls of the *lumina* inwards, must have been somewhat different from those of the former crystallization, which took place within the mass of the whole solidifying rock-matter, where the separate individuals must have crowded upon one another, etc.; hence the ever increasing size of grain, the zonal structure (conditioned by the crystallization from the walls inward), etc. If the magmatic silicate solution were not concentrated to such an extent that the *lumina* were completely filled by its crystallization, first, open drusy cavities must have resulted, which finally through continued circulation might be filled in with minerals deposited from solutions at first still hot but later less and less hot. The filling up of the drusy cavities corresponds according to this interpretation pretty exactly to the complete vein formation of the pegmatitic veins which occur outside the normal-

[1] *l. c.*, 67.

grained rock mass; the explanation throws light in both cases upon the continuous transition from the rock formed purely by magmatic solidification to the final minerals of the druses deposited from solutions not exactly magmatic (less concentrated)."

This statement certainly leaves much to be desired in the way of clearness, and we confess ourselves unable to gather from it with certainty the author's meaning. Considered simply as a suggestion or outline of the mode of formation of pockets, we should not care to criticise it. The references to more and less concentrated magmatic silicate solutions suggest the possible intervention or agency of water; but in view of the facts that this is not explicitly stated and that anhydrous magmas are now generally regarded as true solutions, the idea of minimizing the aqueous influences is obvious. Whether Brögger should really be classed with the advocates of the igneous or the aqueo-igneous theory of pegmatite is ,therefore, doubtful; and it has seemed best to us not to hazard a guess as to the possible hidden meaning of his language.

Aqueo-igneous Theory.

Although the igneous theory, even in its more modern forms, so obviously fails as a complete explanation of pegmatite, yet it is distinctly along this line, from Charpentier's view as a starting point, that we have advanced to the conception of a more perfect cöoperation of heat and water. Referring to William's summary[1] of pegmatite theories we learn that Élie de Beaumont, in his famous essay "Sur les emanations volcaniques et métalliferes,"[2] while accepting in the main the igneous and intrusive origin of pegmatites, introduced an important addition in assuming water and other mineralizing agents as necessary factors in their formation. Scheerer,[3] in a contemporary paper, attributed a still more important rôle to water in the formation of pegmatites, holding what Hunt[4] has designated as the theory of "granitic juice," a highly heated aqueous solution of mineral substances impregnating the congealing mass and oozing out under pressure into the surrounding rocks. Lehmann,[5] in his

[1] U. S. Geol. Survey, Annual Report, 15, 676.
[2] Bull. Soc. Géol. Fr. (II), 4, 12 (1847).
[3] Bull. Soc. Géol. Fr. (II), 4, 468.
[4] Chem. and Geol. Essays, 189, (1875).
[5] Granulitgebirge, 52--58.

large and excellent work upon "The Granulite District of Saxony," as quoted by Brögger, endeavors to account for the pegmatite veins of that region. He assumes the aqueo-igneous (hydatopyrogene) formation of granite, and pronounces the veins in a sense to be injection veins. "The granitic veins of the granulite district have originated, no doubt, with the aid of more or less water, but this has not been atmospheric water which has percolated downwards through the cracks of the granite, but it is eruptive water, which was given up from the granite to the surrounding rocks, and which, under peculiar conditions obtaining at great depths, was supersaturated with mineral matter." Lehmann assumes for the granitic magma a gelatinous consistency, which was to be accounted for, presumably, by the presence of "viscous silicic acid." "These fluid secretions of granite may be compared to hot jelly." . . . "The capacity of silica to form jellies with much or little water invites strongly to this hypothesis." "Between such a gelatinous magma and a saturated aqueous solution a large number of consecutive intermediate stages can be imagined. In this way, it seems to me, the connection between the pegmatitic veins and the ordinary granites, the remarkable segregations in the shape of pegmatitic veins opening out into druses, and finally the connection of these with vein-fillings which consist only of quartz, tourmaline and potash mica, or of quartz alone, can be explained, etc." Lehmann still farther emphasizes the rôle which water plays in the magma in holding that a high temperature is unnecessary to its formation and evolution. The increasing agency of water brings us next to Reyer,[1] who regarded the pegmatites as excretions of the solidifying magma, representing the last stage of solidification where water was largely active, while Keilhau, Hausmann, and Daubrée regarded the pegmatites as mainly aqueous deposits, but genetically connected with granitic intrusions.

Notwithstanding his belief in the igneous origin of pegmatites in general, Brögger accepts the aqueo-igneous theory for a not insignificant proportion of them. He says[2] the pegmatites, although chiefly magmatically solidified veins, pass into the crack-fillings which succeed them in point of time and which are not in the main, or are not at all, deposited from true magmatic solutions. To this he adds in a foot-

[1] Theoretische Geologie, 101 (1888).

[2] Canadian Record of Science, 6, 60.

note, "Many large-grained veins of a pegmatitic structure have been formed principally by pneumatolitic (aqueo-igneous) processes, and not mainly by magmatic solidification," citing as examples the apatite-bearing basic veins and many occurrences of cassiterite, tourmaline, topaz, etc. Also that the muscovite granite pegmatite veins, containing especially beryl, topaz, etc., and having as principal minerals microcline, oligoclase, albite, quartz, muscovite, are, in comparison with the ordinary granite pegmatite veins with which they frequently occur, of somewhat later formation, a slightly different magma, and to a larger extent of pneumatolitic formation.

This review of opinion shows that while several previous writers have recognized the important and necessary agency of water in the formation of pegmatite, varying between heat as the chief agent with water coöperating (igneous processes), and water as the chief agent with heat coöperating (aqueous processes), Lehmann alone has given us a complete statement of the aqueo-igneous theory, or recognized the essential continuity of the igneous and aqueous processes and the consequent complete blending of fusion and solution, and their products — the igneous and aqueous rocks. The present paper may be regarded, therefore, as based upon Lehmann's work — a restatement of his views, with more complete elaboration and illustration in certain directions.

All lavas appear to be more or less hydrated at the time of their extrusion; and, however much opinions may differ concerning the source of the water and its original relations to the magma, it is generally conceded that at the moment of eruption they are very intimately united, and that the former increases the liquidity and the eruptive energy of the latter. Water is very thoroughly diffused through the earth's crust; and it has probably penetrated to so great a depth as to warrant the conclusion that all the so-called igneous rocks now exposed to our observation are in some degree the products of aqueo-igneous fusion. It is unnecessary, however, to insist upon this broad generalization, for, although it may be questioned for some of the plutonic rocks, it is very generally conceded to be true for those with which we now have to do — the acid plutonics or the granites.

The order of crystallization of the component minerals, and the fact that the quartz, which has been in every instance the last mineral to crystallize, is usually crowded with aqueous inclusions, leave no room to doubt that water was present and played an important part in the

formation of granite. It is quite unnecessary to raise here the question as to whether or not the granites are metamorphosed sediments; for those who would answer in the negative must, apparently, concede that there is a hydrated zone of the primitive igneous crust beneath the oldest sediments. In fact, the hydration of the original or still unstratified igneous crust to a great depth below the oldest sedimentary rocks appears to the writers a peculiarly safe assumption, for we have to do here with a portion of the primitive crust which formed the immediate floor of the primitive ocean.

Assuming, then, without farther argument, that the granites have been formed in the presence of water, it may be noted that the number, minuteness, and universal presence of the liquid inclusions indicate that, as in modern lavas, the water was very intimately combined with the granite magma. As the magma cools, the various minerals develop and crystallize out in the general order of their basicity, each, in turn, excluding, so far as possible, the still unindividualized magma and water, just as any crystals formed in a solution exclude the solvent. The magma thus becomes steadily more and more acid and hydrated; and when, finally, the free silica alone remains unsolidified, it is probably combined with sufficient water to hold it temporarily in the gelatinous state. As this gelatinous silica slowly and spontaneously dehydrates and crystallizes it necessarily imprisons the main part at least, of the water, which, like a true solvent, is the only part of the magma that remains permanently unsolidified.

Conceive, now, that a large boss or massif of molten granite has invaded the crystalline schists at a great depth and is undergoing extremely slow refrigeration. Crystallization begins on the surface of the mass and gradually extends inward. The rate of cooling diminishes as the crust thickens, but the highly viscous nature of the cooling magma prevents the formation of large crystals. Finally, however, as the outer shell of the boss becomes gradually thicker, the rate of cooling and crystallization are sufficiently reduced to enable the quartz, as it slowly hardens, to exclude a portion of its inclosed water, forcing it inward into the still liquid magma; which is thus rendered more liquid, but not sensibly so at first, for the slowness of the process permits the diffusion of the excluded water through a large volume of unconsolidated magma. The extremely gradual nature of the changes is an essential feature of the explanation. The feldspar and mica probably crystallize in part at least far in advance of the quartz, forming a

reticulated or sponge-like zone, through the meshes of which the silica gradually expels a portion of its water. This process is, perhaps, favored by the tendency, through contraction, to reduce the pressure in the interior of the mass. The magma thus becomes, although its temperature is slowly falling, more and more liquid, passing gradually from the condition of aqueo-igneous fusion to that of igneo-aqueous solution; and the greater mobility of the latter state permits the formation of larger crystals. We may thus conceive a perfect blending of the conditions favoring the formation of normal granite in the exterior portion of the mass with those favoring the formation of giant granite or pegmatite in the central portion.

Cooling, crystallization, and dehydration are processes involving contraction, and thus, as in a septarian concretion, there is a manifest tendency to form vacant spaces or cracks in the interior of the boss, in which the highly hydrated and liquid residuum of the magma collects and slowly crystallizes. If these cracks extend through the hard crust of the boss into the surrounding or overlying schists, or if fissures due to extraneous causes penetrate the boss, they will become the seats of sharply outlined and typical veins of pegmatite.

The gradual character of every phase in the refrigeration and solidification of the boss makes it absolutely necessary to suppose that there must be somewhere a perfect gradation from the normal granite to the coarsest pegmatite. As previously stated, this gradation may be observed to some extent in the natural ledges; but we may fairly suppose that, while the cooling of the boss would be partly lateral, it would take place mainly downwards; and since distinct veins of pegmatite represent an actual extravasation of the aqueo-igneous magma, it is apparent that the gradation in question should be sought mainly in depth. It appears to us probable that some of the coarser plutonic rocks, like the syenite of Marblehead, Mass., in a portion of which the crystals of feldspar are from four to six inches in length, should be regarded as intermediate between those of more normal texture and pegmatite.

It is, perhaps, not impossible that a portion of the water required for the more perfect hydration and liquefaction of the residuum of the magma may be derived from extraneous sources. The boss is a great body of magma which has been forced up to, or developed in, a position in the earth's crust far above its normal level. It brings the deep-seated temperature and other conditions up into the region of compar-

atively active aqueous circulation; and it may be that shrinkage cracks or faults, if not interstitial percolation in accordance with Daubrée's law, would admit meteoric or relatively superficial waters to a participation in the differentiation of the magma.

There appears to be an opportunity presented, also, to apply Soret's principle, upon which Iddings so largely relies, in his valuable essay on the origin of igneous rocks,[1] as a cause of the differentiation of purely igneous magmas. Soret demonstrated that if two parts of a solution of any salt be kept at different temperatures there will be a concentration of the salt in the cooler part of the solution. Iddings holds that in any molten magma certain oxides play the rôle of solvents for the others. But if Soret's principle admits of application to an anhydrous magma, much more should it be applicable to a magma in a state of aqueo-igneous fusion. In the granite boss the cooler part is the exterior, and toward the exterior, therefore, the dissolved bases will be concentrated, leaving in the interior a more highly hydrated portion, which will be in a state of igneo-aqueous fusion, and from which may be developed the coarse crystallization, comb-structure, and pockets of typical pegmatite. This principle probably coöperates with and is, perhaps, intrinsically more important than that of the exclusion of water by crystallization. The main point of this paper is the explanation of the pegmatites through a differentiation of acid magmas in which water plays an important part, the differentiation involving for the magma residuum a transition from aqueo-igneous fusion to igneo-aqueous solution. The possible intervention of extraneous water has been suggested, but this is not deemed essential.

The increase in the degree of hydration of a small part of the magma, through the exclusion of water during solidification by the remainder, is substantially the explanation which Iddings offers for the phenomena presented by spheratites and lithophysæ. A moderate increase in the proportion of water about centers, the proximity of which will be determined by the viscosity of the magma and the rate of cooling and solidification, gives the unsolidified residuum sufficient liquidity to permit the incipient radial crystallization of the spherulite; while a higher degree of local hydration gives rise to the concentric crystalline shells and shrinkage cracks (pockets) with the highly perfect crystallizations of feldspar, quartz, fayalite, etc., characteristic of the typical lithophysæ.

[1] Bulletin of the Philosophical Society of Washington, 12, 158.

An analogy may also be traced between this explanation of pegmatite and what appears to us to be the best explanation of the quartz geodes in certain limestone formations. Soluble organic silica originally disseminated through the limestone is dissolved by percolating water and subsequently replaces the calcium carbonate of the limestone about favorable centers. The silica is precipitated and accumulates in a highly hydrated and gelatinous form. Its volume is thus sufficient to fill the globular cavity due to the solution of the limestone; and, theoretically, the accumulation continues until the soluble silica in the tributary portion of the limestone is exhausted. The gelatinous silica then slowly dehydrates and solidifies. This process begins at the surface; a continuous and impervious shell is thus formed; and the remaining silica slowly adds itself to the inner surface of the shell. The viscous nature of the hydrate does not allow the molecules of silica sufficient freedom of movement for the development of a visibly granular or crystalline structure; and the outer layer of the shell is, therefore, cryptocrystalline or chalcedonic. But a process of spontaneous differentiation is in progress. The separation of a portion of the silica renders the solution more mobile, the molecules of silica move more freely, so that cryptocrystallization usually gives way to phenocrystallization, and the inner surface of the geode is studded with large and perfect crystals of quartz. The finely crystalline normal granite forming the main part of a boss corresponds to the chalcedonic shell of a geode, and the central veins and masses of pegmatite to the crystalline lining. The much larger proportion of water in the ball of colloid silica from which a geode is evolved determines a greater preponderance of the coarser crystallization and a relatively larger central cavity or pocket than in the granite boss; while the vastly slower crystallization of the boss prevents, as a rule, even the outer part from being left in the semi-amorphous or felsitic condition, which would be essential to give a perfect correspondence with the chalcedonic outer shell of the geode.

We have observed in New Hampshire, as Williams has in Maryland, and other writers in Europe, a perfect gradation in composition between veins of typical pegmatite and ordinary quartz veins. The quartz veins often intersect the pegmatite and are obviously newer; though it is probable that they are usually substantially contemporaneous with the great masses of quartz which are such a characteristic, as well as the latest, feature of the pegmatite. We hold, with Leh-

mann, that the most satisfactory explanation of this blending of pegmatite with quartz veins on the one hand, as with normal granite on the other, is to be found in a corresponding blending of aqueo-igneous fusion with igneo-aqueous solution; and this dynamic gradation, it appears to us, can only result from the gradual hydration of the residual magma during the slow centripetal solidification of a body of magma and a consequent elimination of water.

In any case, the solidification and crystallization of a body of magma must be conceived as centripetal; and this consideration makes it impossible for us to agree with Brögger that the water of any considerable volume of magma would pass outward through the constantly thickening shell of granite into the wall-rock. And before the solidification begins the diffusion of the magmatic water through the wall-rock appears equally improbable, since the magma is to be regarded as a chemical union of water and fused rock, a true hydrate, which is dissociated by crystallization, but while actively molten under pressure, absorbing water rather than giving it off. Furthermore, it appears to us probable, or at least possible, that magma injected into the wall-rock may become more liquid, in spite of cooling, through absorption of water; provided the wall-rock has a high temperature or the magma is already sufficiently hydrated to have a low fusing point. Local absorption of water from the wall-rock would best account for the pegmatitic character of the small dikelets or apophyses of granite to be observed on the shores of Marblehead and Swampscott, Mass. The main body of granite is quite free from pegmatitic characters; but the innumerable branches or apophyses of granite ramifying through the bordering diorite are very generally pegmatitic, at least in part, with frequent gradations, the most typical pegmatite passing by insensible steps into the normal granite on the one hand and ordinary vein quartz on the other. The dikelets vary in size from half an inch or less to several feet in width, even the smallest often exhibiting perfectly the gradation just noted; and the pegmatitic character is quite commonly accompanied by a more or less distinct banding or zonal structure — symmetrical bands of feldspar (red orthoclase) on either wall, with quartz and sometimes epidote and allanite in the middle. Long, narrow pockets are a very characteristic feature of these banded veinlets of pegmatite, indicating a high degree of hydration of the magma.

Although the fluidity of the highly hydrated pegmatite magma

would make extravasation easy, and thus, perhaps, readily account for the size and number of the pegmatite veins in the surrounding formations, and the fact that they sometimes extend to great distances from the parent plutonic mass; yet extravasation of a definite pegmatite magma is out of the question in the Marblehead and Swampscott occurrences, and the pegmatite must be due essentially to a differentiation *in situ* of the normal granite magma, the only cause of the differentiation which we are able to recognize being the absorption of water from the wall-rock. While studying the pegmatites of New Hampshire we were strongly impressed, as already noted, by the number, size, and general prominence of the pegmatite veins in the schists, even at considerable distances from the mother rock — the Concord granite, the pegmatite being quite in contrast, in this respect, with the normal granite, which seems to form but few apophyses or dikes in the schists. In fact, we believe it may be truly said that while pegmatite intrusions are especially characteristic of the schists, intrusions of the normal Concord granite occur chiefly in the more massive formations (Winnipesaukee gneiss, porphyritic granite, etc). These considerations have recently suggested to us the following modification or extension of the pegmatite theory:

Pegmatite magma may be formed in two distinct ways: First, by normal magmatic differentiation in a boss or large body of magma, both crystallization and the operation of Soret's principle tending, as already explained, to increase the degree of hydration of the magma residuum about favorable centers. These magma residues may crystallize *in situ* in the midst of the previously solidified normal granite, giving rise to what may be called sedentary pegmatite, which is especially characterized by its gradual passage outward into the normal granite; or the pegmatite magma may suffer extravasation, finally crystallizing in spaces of discission or dissolution in the parent plutonic, or in the surrounding formations. Second, apophyses of the normal granite magma may invade highly heated, water-bearing formations, such as the schists, and experience the necessary hydration for conversion into pegmatite magma through the absorption of this extraneous water. The high temperature of the wall-rock is essential, as previously noted, to prevent the chilling and crystallization of the magma before the absorption of water can take place.

It cannot be argued that this principle would lead to a peripheral development of pegmatite in the main bodies of granite, for while the

volume of water-bearing wall-rock per unit of surface of the body of magma would not be increased, the volume of magma through which the water would be diffused as fast as absorbed would be enormously greater and no exceptional or marked degree of hydration could result. That the wall-rock must have been highly heated, contrary to Lehmann's view, is reasonably certain from the absence in both the granites and pegmatite of the normal gradation in texture due to the chilling action of the walls. On the other hand, this high temperature probably would not tend to expel the water from the inclosing formations, and thus prevent them from contributing water to the invading magmas; for the well-known experiments of Daubrée and Poiseuille indicate that within certain limits, at least, the heat favors rather than hinders the downward progress of the water in the earth's crust; and it appears to us very probable that the absorption of water by deep-seated magmas is another cause operating to the same end. It can hardly be doubted that the temperature was well above the critical point for water, and hence the hydration of the magma really means the absorption of superheated aqueous vapor under enormous pressure. This extension of the pegmatite theory overcomes the obvious difficulty as to the extensive extravasation of pegmatite magma evolved or originating deep down in a great boss of solidified granite; and apophyses of normal granite accompanying pegmatite may reasonably be referred to a somewhat earlier period, when the thermal conditions were still unfavorable to aqueous absorption.

Pegmatite magma may not only be assumed to be more liquid than that of normal granite, but to solidify less promptly, solidification being due only in part to cooling and in part to spontaneous dehydration,—a general principle, the application of which to the pegmatite magma is indicated by the absence of hydrous species among the component minerals. The experiments of Daubrée and others favor the view that the proportion of water essential to the constitution of the pegmatite magma is small; and this is indicated, also, by the infrequent and relatively small pockets; although the enormous pressure prevailing at these great depths may, perhaps, tend to prevent the formation of pockets.

The origin of pegmatites at great depths is suggested by the regional metamorphism of the schists and the consequent general absence of characteristic or significant igneous contact phenomena; and a high temperature may be inferred from the usually jagged out-

lines of the veins, indicating a tearing or rending, rather than a breaking, of the rocks, as if they had been softened and toughened by heat. The minute, thread-like veins and apophyses, both of pegmatite and common granite, and the very common lack of gradation along the walls for both rocks, are other facts pointing to the same general conclusions. The pegmatite magma is probably very liquid only in pockets; while for the development of the normal pegmatite a much thinner jelly than the normal granite magma, combined, as in the latter, with extremely slow cooling and dehydration, seems to be required. The order of crystallization shows that pegmatite magma is only a more extreme form of the granite magma. In a true igneous or granite magma, however, the size of the crystals is definitely limited by the viscosity; and beyond a certain point it is practically independent of slowness or rate of cooling. It may be noted, also, that while in pegmatite the tabular and prismatic crystals tend to be perpendicular to the walls, in true magmatic consolidation the orientation of the crystals is essentially indifferent to the walls.

The essential continuity of fusion and aqueous solution is not readily demonstrated by experiment. Under the relatively moderate pressures which have been employed, the addition of heat to a solution, beyond a certain low maximum, vaporizes and expels the solvent; and, in like manner, although the addition of water to a magma promotes liquidity, the amount of water which the magma can retain is insufficient to offset the loss of heat due to the vaporization of water. It is clear, however, that with increased pressure solutions might be hotter and fusions more highly hydrated; and we see no reason to doubt that at moderate depths in the earth heat and water may exist in equal and perfect coöperation. Whether at greater depths igneous fusion prevails must depend, of course, upon the temperature and its relations to the elevation of the fusing point by increase of pressure. The absorption of water under pressure by a liquid magma appears to be a chemical process, a true hydration, the water disappearing as such. If this view be correct, there is certainly some reason to think that we have here a reinforcement of Daubrée's explanation of the downward progress of water in the earth's crust. It is not only urged down by capillary attraction, but also, as previously stated, to make good the loss due to its absorption by deep-seated magmas.

Pressure promotes aqueous absorption and solution, but retards fusion by raising the fusing point. High temperatures, on the other

hand, favor fusion, of course, but are antagonistic to aqueous absorption, and hence to solution. If, as we must believe, the pressure increases more rapidly at great depths than the temperature, it may well be, as has been clearly shown by others, that purely igneous fusion nowhere obtains, but the molten magmas at the greatest as well as at moderate depths are in a state of aqueo-igneous fusion. It is a necessary corollary to this view that as refrigeration progresses and water is, in consequence, more abundantly absorbed the degree of liquefaction at a given depth increases until heat and water are in perfect coöperation, and then declines with farther loss of heat, since it is manifestly impossible that sufficient water should be absorbed at any depth to give a general liquid zone by approximately pure solution. It is probable, therefore, that the continuity of fusion and solution is most fully realized during the differential solidification of a body of magma; and pegmatite is, in a truer sense than any other lithologic type, the connecting link between the igneous and aqueous rocks.

Strictly speaking, nearly all, if not quite all, known rocks are secondary. This is generally conceded for the sedimentary rocks; but, following Iddings and other recent writers, it must be admitted also for the igneous rocks. A dike is a more or less highly differentiated portion of some deep-seated magma, and it is clearly newer than the walls. An ascensionist, certainly, can say nothing more for a vein, save that while in the formation of the dike heat is the chief agent with water coöperating (aqueo-igneous fusion), in the formation of the vein water is the chief agent with heat coöperating (igneo-aqueous solution). The greater mobility of the solution permits a higher degree of concentration; but concentration is a universal process and participates in the formation of eruptive masses and sedimentary deposits as well as of veins.

In the opinion of the writers, no sharp line of demarcation can be drawn between dikes and veins, and veins are clearly entitled to some degree of recognition in the lithological classification. In a broad view of the early history of the earth, all the sedimentary and vein rocks are, of course, secondary with reference to the primitive igneous crust, but so are the igneous rocks with which we are now acquainted. Probably none of the igneous rocks which have been studied are truly primitive, and their derivation in some cases from sediments is claimed by many able observers.

Heat and water are the two great agents concerned in the modification and differentiation of the earth's crust; and they are generally, if not everywhere and always, in coöperation, heat prevailing, as a rule, at great depths, and water at the surface. Thus arise the two principal classes of rocks — igneous and aqueous. In either class the rocks may be deep-seated (newer than both walls) or superficial (newer than one wall), in other words, intrusive or contemporaneous. The intrusive igneous masses are known as dikes, etc., and the contemporaneous as lava-flows; while the intrusive aqueous masses are known as veins, etc., and the contemporaneous as sedimentary strata. Between the vein rocks and dike or plutonic rocks we have, at great depths, a perfect transition, in the pegmatites; but between volcanic rocks and sediments transition forms are wanting, because the limited pressure does not permit the perfect coöperation of heat and water.

Since this paper was written, the *16th Annual Report of the United States Geological Survey* has appeared, containing Van Hise's important discussion of the principles of Pre-Cambrian geology. We are pleased to see (p. 687) that he holds very strongly to the essential continuity of fusion and solution at great depths in the earth, and finds in this coöperation of aqueous and igneous agencies the best explanation of the main part at least of the pegmatites, although holding with Brögger that they are in part of normal igneous origin.

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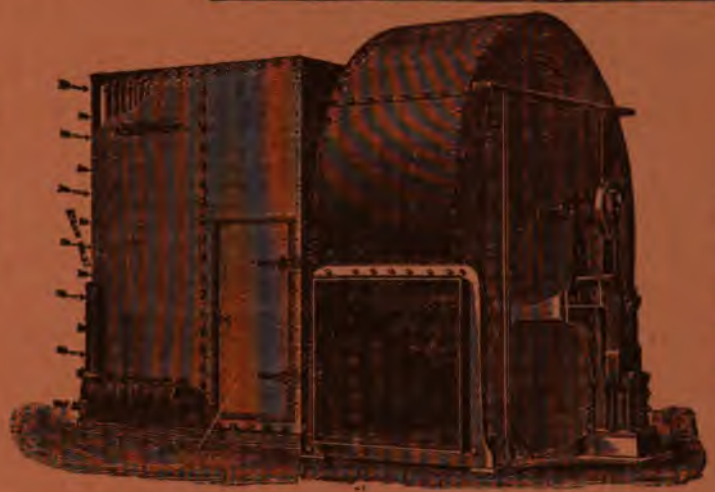

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REVIEW OF AMERICAN CHEMICAL RESEARCH.

VOL. II, NO. 1.

EDITED BY ARTHUR A. NOYES.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

The Chemical Kinetics of Oxidation. BY HERMAN SCHLUNDT AND ROBERT B. WARDER. **II. Mathematical Theory of Oxidation Processes.** BY ROBERT B. WARDER. *Am. Chem. J.*, 18, 23–43. — This article is a discussion of Schlundt's results, which have been previously reviewed (*Tech. Quart.*, 8, 395). The reviewer is unable to find that new facts of importance have been established by the application of the mathematical theory to the results, or that the theory itself has been further developed.

Third Annual Report of Committee on Atomic Weights. Results Published During 1895. BY F. W. CLARKE. *J. Am. Chem. Soc.*, 18, 197–214. — A summary is given of the atomic weight determinations published during the preceding year, the mean results of which are given below (O = 16):

Hydrogen (MORLEY, *Smithsonian Contributions to Knowledge*)	1.0076
Hydrogen (THOMSEN, *Ztschr. anorg. Chem.*, 11, 14)	1.0082
Cobalt (THIELE, *Dissertation*)	58.912
Zinc (RICHARDS and ROGERS, *Ztschr. anorg. Chem.*, 10, 1)	65.404
Cadmium (BACHER, *Dissertation*)	112.39
Molybdenum (SEUBERT and POLLARD, *Ztschr. anorg. Chem.*, 8, 434)	96.00
Tellurium (STAUDENMEIER, *Ztschr. anorg. Chem.*, 10, 189)	127.3
Yttrium (JONES, *Am. Chem. J.*, 17, 154)	88.95
Cerium (SCHÜTZENBERGER, *C. r.*, 120, 663)	139.96
Cerium (BRAUNER, *Phil. Trans.*, 186, 220)	140.01

H. M. GOODWIN, REVIEWER.

Heats of Solution of Some Carbon Compounds. BY C. L. SPEYERS. *J. Am. Chem. Soc.*, 18, 146. — The following results were obtained for the heats of solution of various solid (pulverized) carbon compounds by Nernst's familiar method. A Beckmann thermometer was used to measure the temperature. The figures give the heat of solution, expressed in small calories, of 1 gram-molecule of substance.

NOTE. — Beginning with the current issue, the pages of the *Review of American Chemical Research* will be numbered separately from the rest of the *Quarterly*, in order that the several parts may be bound together at the end of the volume.

	Water.	Methyl Alcohol.	Ethyl Alcohol.	Propyl Alcohol.	Chloroform.	Toluene.
Urea	—3628	.....	—3612	.....	.....	.....
Urethane	—3787	—4345	—4728	—6045	—4573	—6399
Chloral Hydrate . .	— 929	.....	—1131	.....	—5993	—7537
Succinimide	—4294	.....	—5456	.....	.....	.....
Acetamide	—1991	.....	—3606	.....	.....	.....
Mannite	—5262	.....	.....	.....	.....	.....
Resorcine	—3960	.....	+ 269.2	.....	.....	.....
Benzamide	.....	.....	—4238	.....	.....	.....
Toluidine (*p*) . . .	.....	.....	—3650	.....	—3492	—4983
Acetanilide	.....	—4477	—4212	.....	—4442	.....
Acenaphthene . . .	.....	—6180	—5986	—6807	—4480	—4788
Naphthalene . . .	.....	—4233	—4861	—5681	—3852	—4267
Phenanthrene . . .	.....	.....	—4306	.....	.....	—3528
Sugar	—1318	.....	.....	.....	.....	.....

On the Viscosity of Certain Salt Solutions. By B. E. Moore. *Phys. Rev.*, 3, 321–334. — The viscosity referred to water at 18° C. of aqueous solutions of neutral and acid sodium and potassium carbonate, sulphate and phosphate, as well as the hydrate and oxalate of the same metals, was determined by means of Arrhenius' viscosity pipette. The concentrations varied in different cases from about 2.0 normal to 0.125 normal. The hydrates were investigated up to 6.8–8.0 normal. — It was found that the viscosity of the sodium salts was in all cases greater than that of the corresponding potassium salt, and that both were greater than that of the corresponding acid, as previously found by J. Wagner. This was very marked in the case of the phosphates. A comparison with conductivity values showed that when the conductivity of a series of salts increased the viscosity sometimes increased and sometimes diminished, according to the nature of salts compared, no definite relation between the two being apparent. The author states that his results on concentrated solutions do not confirm Arrhenius' exponential law. No new stochiometrical relations appear from the results.

The Surface Tension of Liquids. By Arthur L. Foley. *Phys. Rev.*, 3, 381–386. — The method is essentially that described by Hall, and consists in measuring the maximum weight of liquid raised by a frame brought into contact with the liquid. The author describes a new form of mica frame, better suited for accurate work than the glass form previously employed, and gives the results of a few preliminary measurements on the surface tension of water.

On the Freezing Point of Dilute Solutions. By E. H. Loomis. *Phys. Rev.*, 3, 270–292. — This article is a continuation of the well-known work on this subject by the author, and contains measurements on the following electrolytes: Potassium, ammonium, barium, and magnesium chlorides, hydrochloric acid, potassium and sodium sulphates, carbonates and nitrates, ammonium nitrate, and phosphoric acid. The method was essentially that previously employed, with the exception that 200 cc. instead of 70 cc. solution was used to reduce the effect of external temperature changes. Care was taken to maintain the temperature of the room in which the measurements were made as constant and as near 0° C. as possible. The freezing mixture was 0.3° C. below the freezing point of the solution, it being found by experiment that this temperature reduced the "convergence temperature" (Nernst) to the actual freezing point sought. The solutions investigated varied from 0.2–0.3 normal to 0.01 normal. — It appears from the results that the molecular lowering continually increases with the dilution, with the exception of that of magnesium chloride and hydrochloric acid, which show a minimum depression at $m = 0.10$. The electrolytes studied divide themselves into two groups — the first made up of compounds containing univalent acidic and basic radicals, the second of those with bivalent radicals. The latter group is distinguished from the former in that the amount of its molecular depression and its rate of increase in dilute solutions are greater. At extreme dilution the molecular depressions of all salts in the same group converge towards the same limiting value. The apparent exceptions in the case of ammonium chloride, potassium nitrate, and barium chloride are probably due to experimental error. Magnesium sulphate shows abnormally low values, as previously observed by others. — A comparison of the observed depression of the freezing point with that calculated from dissociation values computed from Kohlrausch's conductivity measurements shows in general an agreement in dilute solution of about 2.5 per cent., and in more concentrated solutions of about 3 per cent. As this corresponds to an error in the hundredths of a degree in the molecular lowering, an amount much beyond the experimental error, the author concludes that the deviations are real and not apparent. [It should not be lost sight of, in the case of compounds containing bivalent radicals, that, if the dissociation takes place in any other way than into the ultimate simple ions, an exact agreement between dissociation values computed from conductivity and freezing-point measurements is not to be expected.] — From a careful study extending over several months of the variation of the zero point of the thermometer, and from the concordance of independent series of observations, the author concludes that, with all possible precautions, the experimental error with a mercurial thermometer may amount to 0.001°, an amount fatal to the measurement of the depression of the freezing point of solutions diluter than 0.01 normal.

Some Questions in Regard to the Author's Method of Measuring Freezing Points of Dilute Solutions. By E. H. Loomis. *Phys. Rev.*, 3, 293–301. — The author considers in detail the various questions which have been raised by different investigators in regard to his previously published results. He points out clearly and correctly the misleading and erroneous conclusions of Wildermann. The question of the $\frac{1}{10000}$ degree *versus* $\frac{1}{1000}$ degree thermometer is again discussed, and the advantages claimed by Jones and Wildermann for the former are found to be unwarranted. The author bases this conclusion on the firm conviction that the freezing point

of a solution cannot be successively established closer than 0.001°, and that this and not the reading of the thermometer is the fundamental cause conditioning the true experimental error of a determination.

Inorganic Chemistry.

H. Fay, Reviewer.

Derivatives of Columbium and Tantalum. By Mary Engle Pennington. *J. Am. Chem. Soc.*, **18**, 38–67. — Columbite from Wakefield, N. H., was analyzed by decomposing the mineral with acid potassium sulphate. Tantalum, columbium, and titanium were not separated, but weighed together. Ferrous iron was determined by fusion with borax, this method giving better results than the decomposition with sulphuric acid in a sealed tube. The mineral contains: (Ta_2O_5 + Cb_2O_5 + TiO_2), 78.04; (WO_3 + SnO_2), 0.24; U_3O_8, 0.48; Fe_2O_3, 5.22; FeO, 6.42; CaO, 0.02; MnO, 8.96; H_2O, 1.22. The decomposition of the mineral was most easily accomplished by Gibbs' method of fusing with potassium fluoride and hydrofluoric acid. It serves the purpose for preparing large quantities of the pure oxides. The separation of the oxides was accomplished by means of the insoluble tantalum potassium fluoride. An excess of potassium thiocyanate added to a small amount of any soluble compound of columbium, and then some zinc, followed by strong hydrochloric acid, gives a golden brown color — red if much columbium is present — which distinguishes this element from titanium and tantalum. A table of the various wet and dry qualitative reactions is given. In general, the reactions of the tantalates, columbates, and titanates are different from those of the double fluorides of these elements. The action of the electric current on the double fluorides, $2KF.CbOF_3.H_2O$ and $2KF.TaF_5$, gives a lower hydrated oxide. By heating the oxides of columbium and tantalum in a closed tube with phosphorus pentachloride, the pentachlorides of the metals and phosphorus oxychloride are formed. During the course of the investigation the following double fluorides were prepared: $2RbF.TaF_5$, $2RbF.TiF_4$, $15CsF.TaF_5$, $7CsF.CbF_5$, $4CsF.TiF_4$.

Some of the Properties of Liquid Hydriodic Acid. By R. S. Norris and F. G. Cottrell. *Am. Chem. J.*, **18**, 96–105. — Hydriodic acid prepared from red phosphorus and iodine, and carefully dried by phosphorus pentoxide, was condensed by means of solid carbon dioxide to a colorless, limpid liquid, and a study of the reactions of this liquid was made on the various metals. The reaction with silver, mercury, tin, iron, and aluminum was quite rapid, with evolution of hydrogen and the formation of the corresponding iodide. Copper dissolves more slowly. The action of the liquid on metallic sodium was slow at the freezing point of the acid, but became more rapid as the temperature increased; the action on potassium was violent at the melting point of the acid. Lead, bismuth, cadmium, antimony, zinc, and thallium were unacted upon, the surface of the metal becoming only slightly tarnished. With arsenic, magnesium, and silicon there was no reaction whatever. Copper oxide and manganese dioxide dissolve with liberation of iodine. Neither calcium nor sodium carbonates are attacked by the liquid acid. — The authors also made a study of the liquid acid on other liquified gases. Chlorine combines directly with liberation of iodine and formation of iodine trichloride. Cyanogen forms hydrocyanic acid and iodine, and sulphur dioxide yields hy-

drogen sulphide, sulphur, and iodine. Liquid ammonia combines directly to form ammonium iodide. Absolute alcohol or ether mixed with the acid combine, forming a sirupy liquid, which separates into two layers consisting of an aqueous solution of hydriodic acid and ethyl iodide. It is worthy of note that water does not mix with the liquid acid even when shaken with it.

On the Preparation of Hydrobromic and Hydriodic Acid. By J. H. Kastle and J. H. Bullock. *Am. Chem. J.*, 18, 105–111. — The author proposes two very convenient methods for the preparation of hydrobromic and hydriodic acids, and suggests certain experiments with the pure dry gases for lecture room work. To prepare hydrobromic acid 15–20 grams of naphthalene are dissolved in a small quantity of orthoxylene and the solution placed in a Florence flask of one-half liter capacity. This flask is connected with a Woulff's bottle containing a small amount of hydrobromic acid, in which there is some suspended red phosphorus, and this in turn is connected with a U tube containing red phosphorus and several tubes containing phosphorus pentoxide. The bromine is introduced into the solution of naphthalene by means of a dropping funnel reaching below the surface. The reaction takes place at once, and the flow of gas can be easily regulated. Instead of using orthoxylene as the solvent, it was found that kerosene oil boiling above 150° C. gives results just as satisfactory. The ordinary *moth ball* furnishes naphthalene of sufficient purity. — To prepare hydriodic acid 10 grams of finely divided iodine are mixed with an equal weight of finely powdered resin, and this mixture is thoroughly mixed with a little more than an equal bulk of white sand. The glass retort in which this is placed is connected with one of the necks of a double-necked Woulff's bottle, the other neck being connected with a U tube containing red phosphorus and a calcium chloride tower filled with alternate layers of glass wool and phosphorus pentoxide. On gently heating the retort, hydriodic acid is freely evolved, together with small quantities of iodine and a small amount of a brown liquid which collects in the Woulff's flask. Perfectly colorless, dry hydriodic acid gas can be collected in this way.

Mixed Double Halides of Platinum and Potassium. By Charles H. Herty. *J. Am. Chem. Soc.*, 18, 130–142. — A series of mixed double halides of platinum and potassium, beginning with K_2PtBr_6Cl and ending with K_2PtCl_6Br, was obtained by Pitkin by bringing together in definite proportions potassium platinichloride and potassium platinibromide. He concluded that the salts were definite chemical compounds rather than isomorphous mixtures from the fact that on fractional crystallization there should be greater separation of the more insoluble compound, while on repeated crystallization more of the soluble compound would remain. This he did not find to correspond with the facts. The author having recently shown that the double halides of lead and potassium, and of antimony and potassium containing more than one halogen, are isomorphous mixtures of the double halides containing one halogen, repeats Pitkin's work, using improved methods of analysis and taking great care to start with pure materials. Four solutions were prepared, each containing the same amount of chlorplatinic acid. In one was used a definite amount of potassium bromide, and in the other three arbitrarily selected portions of the potassium bromide were replaced by equivalent portions of potassium chloride. In each solution bright red octahedral crystals were obtained, the color becoming lighter with the increased amount of potas-

sium chloride present. From the analyses it was evident that four different substances were obtained, each differing from the two nearest members of the series described by Pitkin, $K_2PtCl_4Br_2$ and K_2PtCl_5Br. Successive crops of the crystals varied in composition, showing gradually increasing proportions of the more soluble potassium platinibromide and correspondingly decreasing proportions of the potassium platinichloride. On recrystallization from water the first crop of crystals is not identical with the original substance, but is a product richer in chlorine. Treating one of the substances with an insufficient quantity of water for complete solution, the more soluble bromide was dissolved from the mass to a greater extent than the chloride. None of the substances prepared correspond to the formula of Pitkin, but all show an approximate atomic ratio; platinum to chlorine and bromine, 1 : 6. From this evidence the author concludes "that the double halides of platinum and potassium containing more than one halogen are isomorphous mixtures of different double halides containing only one halogen."

Probable Production of Permanganate by Direct Combustion of Metallic Manganese. By GEORGE C. STONE. *J. Am. Chem. Soc.*, 18, 230. — The author noticed the purple color of a permanganate solution when some water was accidentally spilled on a sheet-iron screen used to cover the tap-hole at a Spiegel furnace, and suggests the probable direct oxidation of manganese to a permanganate.

On the Reduction of Sulphuric Acid by Copper as a Function of the Temperature. By LAUNCELOT ANDREWS. *J. Am. Chem. Soc.*, 18, 251–254. — To determine whether sulphuric acid is reduced by copper to sulphur dioxide at a higher or lower temperature than the point of dissociation of sulphuric acid, copper was heated with pure sulphuric acid in a bath, while a current of dry air or carbon dioxide was passed through. The escaping gas was absorbed and tested by suitable reagents. The dissociation of the sulphuric acid when heated alone was found to begin at 67° C. When pure sulphuric acid, to which pure copper had been added, was allowed to stand several hours at the ordinary temperature, and a current of air was passed through, there was no decolorization of the iodide of starch solution in the receiver, but much of the copper had been converted into sulphate, the reaction being represented in this way: $2Cu + O_2 + 2H_2SO_4 = 2CuSO_4 + 2H_2O$. If carbon dioxide be substituted for the air, the copper is not attacked, and there is no change in the iodide of starch solution until the bath surrounding the sulphuric acid shows a temperature of 90° C. When a solution of barium chloride, colored by potassium permanganate, was used to receive the gases there was precipitation of barium sulphate at 70° C., and at 86° C. the permanganate was reduced by the sulphur dioxide, showing that the sulphuric acid is not reduced until after the point of dissociation is reached. These results disprove the assertion of Baskerville, who stated that sulphuric acid is reduced by copper at 0° C., the author thinking that the reduction noticed was due to the presence of air.

The Oxidation of Silver. By CHARLES E. WAIT. *J. Am. Chem. Soc.*, 18, 254–259. — This paper is a study of the conditions under which silver is oxidized at a high temperature. Finely divided metallic silver was heated with the oxides of different metals, and the resulting oxide of silver was separated from metallic silver by means of acetic acid. In case lead oxide was

used it was found necessary to remove the lead before determining silver. The formation of silver oxide varied from only a trace to 39 per cent. of the silver, depending on the oxide used, the temperature, and time of heating. With the oxides of zinc, iron, copper, and bismuth, or with calcium carbonate, there was no formation of silver oxide, but with manganese dioxide the results vary from 7.78 per cent. of silver oxide formed to 34.28 per cent., depending on the proportions and time of heating. The oxidation also takes place in the presence of lead and barium peroxides.

On Silicides. By G. de Chalmot. *Am. Chem. J.*, 18, 95. — Copper heated in an electric furnace with an excess of sand and charcoal gives a silicide of the probable composition Cu_2Si_3, which crystallizes in flat, brilliant, bluish white, metal-like crystals. When a mixture of silica, carbon, and lime is subjected to a direct electric current of high amperage and low voltage, and the cathode is made of copper, a still larger percentage of silicon can be united with the copper. In this way an alloy was obtained containing 51.51 per cent. of silicon, 43.52 per cent. of copper, and some calcium. Silicide of silver, containing some calcium, was made by subjecting a mixture of sand, charcoal, lime, and silver to a current of 240 amperes and 25 volts. It is apparently homogeneous and crystalline. Only part of the silver was dissolved by boiling with dilute nitric acid for seventy-five minutes.

On the Double Fluorides of Cæsium and Zirconium. By H. L. Wells and H. W. Foote. *Am. J. Sci.*, 1 [4], 18–20. — The double salts were prepared by mixing solutions of the two fluorides, in widely varying proportions, in the presence of more or less hydrofluoric acid and evaporating to crystallization. When cæsium fluoride is in excess, the salt $2CsF.ZrF_4$ is formed, crystallizing in large hexagonal plates. By using a larger proportion of zirconium fluoride the salt $CsF.ZrF_4.H_2O$ is formed, crystallizing in monoclinic crystals. Both of these salts can be recrystallized. When a large excess of zirconium fluoride is used, small, difficultly soluble crystals of the salt $2CsF.3ZrF_4.2H_2O$ are formed. It cannot be recrystallized from water, the product being mixed with the 1 : 1 salt. To determine cæsium and zirconium the fluorides were converted into sulphates, then zirconium was separated from cæsium by the use of ammonia, and zirconium oxide and cæsium sulphate were finally weighed. The fluorine was determined in a separate sample, the zirconium being removed as hydroxide. To the filtrate sodium carbonate was added in slight excess, and the ammonia was removed by evaporation. Calcium nitrate was then added to the hot solution, and after ignition the calcium fluoride was washed with formic acid until effervescence ceased. The analytical results varied considerably from the theoretical values. The following table gives Marignac's potassium and ammonium salts, together with those of cæsium prepared by the authors:

3 : 1 Type.	2 : 1 Type.	1 : 1 Type.	2 : 3 Type.
$3NH_4F.ZrF_4$	$2NH_4F.ZrF_4$	.....	.....
$3KF.ZrF_4$	$2KF.ZrF_4$	$KF.ZrF_4.H_2O$	.....
.....	$2CsF.ZrF_4$	$CsF.ZrF_4.H_2O$	$2CsF.3ZrF_4.2H_2O$

The Molecular Weight of Sulphur. By W. R. Orndorff and G. L. Terrasse. *Am. Chem. J.*, **18**, 173–207. — The authors determine the molecular weight of sulphur by the cryoscopic methods, using solvents boiling above and below the melting point of sulphur. In the solvents carbon disulphide, benzene, and toluene, whose boiling points are below the melting point of sulphur, the molecular weight found is 288, corresponding to the molecular formula S_9. At temperatures above the melting point of sulphur, using meta-xylene, phenetol, phenol, and naphthalene as solvents, the molecular weight found was 256, corresponding to the formula S_8. Dissolved in sulphur chloride, the molecular weight is found to correspond to the molecular formula S_2. The molecular weight obtained by the freezing-point method, using naphthalene and diphenyl, cannot be relied upon, as the results do not agree with each other nor with those obtained at the same temperatures by the boiling-point method. The authors give a historical review of previous work on the molecular weight of sulphur.

Hydrofluoric Acid. By Karl F. Stahl. *Proc. Eng. Soc. W. Pa.*, **12**, 55–70. — In this paper the author considers the impurities in hydrofluoric acid and methods of determining them, and the commercial uses of the acid. The most common impurities are sulphuric and hydrofluosilicic acids. To determine the former a weighed portion is evaporated on the water bath, and the residue is titrated with standard alkali. The hydrofluosilicic acid is determined in a separate sample by treating a weighed portion with potassium carbonate and alcohol; the precipitated potassium silicofluoride is filtered off and titrated with standard sodium hydroxide, using phenolphthalein as indicator. The reaction takes place in this way: $K_2SiF_6 + 4NaOH = 4NaF + 2KF + SiO_2 + 2H_2O$. In a separate sample the total acid is determined by titration with standard alkali, and the amount of hydrofluoric acid calculated from this. It is interesting to note that hydrofluoric acid is being used largely to clean castings from sand, and is gradually supplanting the mechanical processes. The acid or its salts are also used in distilleries to insure more complete fermentation. A more recent use is the opening up of oil wells which have been closed by rock from blasting.

Organic Chemistry.

J. F. Norris, Reviewer.

On the Constitution of Phenoquinone. By C. Loring Jackson and George Oenslager. *Am. Chem. J.*, **18**, 1–22. — The present paper is a discussion of the constitutional formula of phenoquinone put forward by Jackson and Grindley in an article on the hemiacetals published last year (*Am. Chem. J.*, **17**, 577; *Tech. Quart.*, **8**, 427). As the latter compounds are formed theoretically by the addition of two molecules of alcohol to quinones, and phenoquinone is formed by the addition of two molecules of phenol to quinone, a formula for phenoquinone is proposed analogous to that established for the hemiacetals, $C_6H_4(OH)_2$ (1) (4), $(OC_6H_5)_2$ (1) (4). A similar structure is assigned to quinhydrone. The fact that quinone combines with two molecules of monatomic phenols, but with only one molecule of diatomic phenols, is in accord with these formulæ. Further, no compound with this formula could be formed from a phenol ether which contained no free hydroxyl, and, in fact, dimethylhydroquinone does not act on quinone. The hemiacetals are bodies of slight stability; phenoquinone and quinhydrone are even less sta-

ble. This lower stability is what would be expected, as the study of the hemiacetals showed that those with the largest number of negative radicals on the quinone ring were the most stable. The action of acetic anhydride on quinhydrone, giving quinone and diacetylhydroquinone, is in accord with the formula given, and not a proof that the body contains no hydroxyl groups, as adduced by Nietzki. Dimethylhemiacetal when treated with acetic anhydride gives the substituted quinone from which it is derived and methylacetate, thereby undergoing a decomposition similar to that of quinhydrone. The sodium salt of phenoquinone was formed by the action of sodium phenylate on quinone, and of sodium naphthylate on phenoquinone. There are marked differences between the properties of the hemiacetals and the members of the phenoquinone group; the former are white and nearly insoluble, while the latter are colored and soluble in many of the organic solvents. Experiments on the diamyl- and dibenzylhemiacetals, undertaken to discover whether this difference was due to the presence of fatty or aromatic radicals, showed that they were colorless and insoluble like the hemiacetals with less complex radicals. These substances and the corresponding quinones and hydroquinones are described in detail. A number of experiments on the formation of substances similar to phenoquinone were made, in order to determine the conditions necessary for making substances of this class. These experiments, together with a new hemiacetal from thymoquinone and hydroquinone and the characteristic phenomena attending the melting of quinhydrone, are described.

Some Derivatives of Unsymmetrical Tribrombenzol. By C. Loring Jackson and F. B. Gallivan. *Am. Chem. J.*, 18, 238–252. — The structure of the tribromdinitrobenzene, melting at 135°, was established in the following manner: The compound was reduced with tin and hydrochloric acid and a monobromphenylene diamine, melting at 93°–94°, obtained, which was converted by bromine water into a tetrabromphenylene diamine, melting at 213°. This latter compound has been prepared from tetrabromdinitrobenzene, in which the nitro groups are in the meta position to each other. The structure is, therefore, Br (1), Br (2), NO_2 (3), Br (4), NO_2 (5). The compound resembles tribromtrinitrobenzene in its reactions with aniline and sodium ethylate. When treated with the former two atoms of bromine are removed, and a brominated dinitrobenzene, melting at 191°–192°, is formed. With the latter two or more organic products result — a bromdinitrophenol, melting at 67°, formed by replacing the two more loosely attached atoms of bromine by ethoxyl radicals, and a tribromresorcine diethylether, melting at 158°, formed by the replacement of the two nitro groups by ethoxyl radicals. A third product obtained in small quantity was not investigated. Sodium malonic ester gave a trace of a red sodium salt. The constitution of the tetrabrombenzene, melting at 175°, was shown to have the symmetrical structure which has been assigned to it without experimental proof. A new tribromaniline, NH_2 (1), Br_3 (2) (4) (5), was prepared. It melts at 80°, and its acetanilide at 188°. It forms salts with greater ease than the ordinary tribromaniline. Its chloride, bromide, and sulphate were analyzed. An attempt to prepare nitro compounds from symmetrical tetrabrombenzene was unsuccessful, the product being hexabrombenzene.

Turmerol. By C. Loring Jackson and W. H. Warren. *Am. Chem. J.*, 18, 111–117. — Turmerol, the oily extract of turmeric, after repeated fractionation under reduced pressure, boiled at 158°–163° (11–12 mm.), and gave

analytical results agreeing with the formula, $C_{18}H_{18}O$ or $C_{14}H_{20}O$. Its specific gravity at 24° is 0.9561; its specific rotation, $[a]_D = 24.58°$. It mixes with the common organic solvents, but is insoluble in water. The fact that dilute nitric acid oxidizes turmerol to paratoluic acid proves that it contains a benzene ring and a long side chain of six (or seven) carbon atoms para to the methyl group. That one of the carbon atoms in the side chain is unsymmetrical is shown by the fact that turmerol exhibits circular polarization.

Certain Bromine Derivatives of Resorcine. By C. Loring Jackson and F. L. Dunlap. *Am. Chem. J.*, **18**, 117–132. — Jackson and Warren showed some time ago (*Am. Chem. J.*, 15, 641) that when tribromnitroresorcine diethylether was heated with a solution of sodium ethylate two bromine atoms were replaced by hydrogen, with the formation of the compound, $C_6H_2BrNO_2(OC_2H_5)_2$. The authors find that tribromresorcine diethylether does not give up bromine to sodium ethylate at the boiling point of alcohol, and that the dibrom ether is not attacked below 200°. Bromine could be removed from free tribromresorcine with great ease. Boiling water, solutions of sodium carbonate, sodium hydroxide, or sodium ethylate in alcohol, caused a breaking down into brown amorphous bodies which could not be purified. From their properties it can be inferred that they are substituted resorcine ethers, formed by a reaction involving the hydroxyl groups of the tribromresorcine. Sodium malonic ester gave a similar unmanageable product and acetylenetetracarboxylic ester. The tribromresorcine diethylether melts at 68°–69°, and is formed by the action of an excess of bromine on the dibromresorcine diethylether (melting point 99°–100°). The tribrom product was shown to have the bromine atoms in the symmetrical position to each other by treatment with nitric acid. This converted it into tribromnitroresorcine diethylether, which is made from symmetrical tribromtrinitrobenzene. Dibromresorcine diethylether when treated with nitric acid gave a new dinitroresorcine diethylether, melting at 126°, formed by the replacement of the two atoms of bromine by two nitro groups. The important point established by the above facts is that in these cases hydroxyl or ethoxyl radicals have the same effect upon bromine as they have upon hydrogen attached to the benzene ring. Dibromresorcine diethylether in its action with nitric acid is an exception to the rule, although it shows great stability toward other reagents. The sodium salt of tribromresorcine was obtained in white crystals by precipitating an ethereal solution with alcoholic sodium ethylate. After standing a short time, even *in vacuo* or in an atmosphere of hydrogen, it suddenly turned black, and alcohol vapor was given off with evolution of heat.

Trinitrophenylmalonic Ester. By C. Loring Jackson and C. A. Soch. *Am. Chem. J.*, **18**, 133–141. — Trinitrophenylmalonic ester was formed by the action of picrylchloride on sodium malonic ester. From its solution in alcohol, which has a marked pink color, it crystallizes in white plates, melting at 58°. It forms a blood-red sodium salt, soluble in water without decomposition, which shows a tendency to explode when dry. When treated with bromine it gives picrylbrommalonic ester, $C_6H_2(NO_2)_3CBr(COOC_2H_5)_2$, melting point 85°–86°, in which the position of the bromine atom was shown by the absence of acid properties in the compound. A bromdinitrophenylbrommalonic ester was also prepared, white crystals, melting at 72°–73°.

On the Action of Phosphorus Pentachloride on Parasulphaminebenzoic Acid. By Ira Remsen, R. N. Hartman, and A. M. Muckenfuss. *Am. Chem. J.*, **18**, 150–170. — By the action of phosphorus pentachloride on

parasulphaminebenzoic acid at varying temperatures a series of compounds has been prepared which are of considerable interest, as they give some insight into the nature of the reactions that lead to the shifting of the nitrogen atom from the sulphone group to the carbon atom in the para position. 10 grams of the acid and 21 grams of phosphorus pentachloride are heated to 60° cautiously until the evolution of hydrochloric acid is complete. The temperature is then raised to 110° to drive off the phosphorus oxychloride, and the resulting colorless liquid extracted with ligroïn at 70°. Transparent prisms separate which absorb water from the air, give off hydrochloric acid, and turn white. They dissolve quickly in warm water, and pure parasulphaminebenzoic acid is deposited. As the solution contains only hydrochloric and phosphoric acids, the constitution of the compound, phosphochloroparasulphaminebenzoic chloride, is represented by the formula, $p\ C_6H\langle^{COCl}_{SO_2.N:PCl_3}$. When the phosphochloride is heated it melts at 82°, and gives off phosphorus oxychloride at 146°. The temperature was raised to 200°, when a charred mass remained, which was extracted with benzene and evaporated to dryness. When this residue was distilled with water-vapor parachlorbenzonitrile passed over, and hydrochloric and paracyanbenzenesulphonic acids remained behind. When parasulphaminebenzoic acid and two molecules of phosphorus pentachloride are heated carefully to 200°, paracyanbenzenesulphone chloride, $p\ C_6H_4\langle^{CN}_{SO_2Cl}$, transparent rhombic prisms from benzene, not attacked by cold water, is formed. It melts at 111°–112°, and sublimes in rough white needles; when heated to 250° it is gradually decomposed, giving off sulphur dioxide and forming parachlorcyanbenzene. When the chloride is boiled with water it is converted into paracyanbenzenesulphonic acid, and when heated with water in a sealed tube to 200° it yielded the acid ammonium salt of parasulphobenzoic acid. The barium and potassium salts and amide of paracyanbenzenesulphonic acid are described. The anilide was made and transformed into parasulphanilidobenzoic acid, $p\ C_6H_4\langle^{COOH}_{SO_2.NHC_6H_5}$, the potassium and barium salts of which are also described. Analogous derivatives from ortho-, meta-, and paratoluidine were formed. When parasulphaminebenzoic acid and phosphorus pentachloride are heated to 250°, sulphur dioxide is evolved and parachlorcyanbenzene distills off as an oil which soon solidifies. It resembles the isomeric ortho and meta compounds closely. It has a peculiar aromatic odor, melts at 83°–84°, and is very volatile, subliming at low temperatures.

On Halogen Addition-Products of the Anilides. By H. L. Wheeler and P. T. Walden. *Am. Chem. J.*, 18, 85–90. — The product described as a dibromine addition-product of metanitroacetanilide in a recent paper by Wheeler (*Am. Chem. J.*, 17, 612; *Tech. Quart.*, 8, 421) on further investigation proved to be a mixture of the perhalides $(C_6H_4.NO_2.NHCOCH_3)_2HBr.Br_2$ and $(C_6H_4.NO_2.NHCOCH_3)_2HBr.Br_4$. An attempt to prepare bromine addition-products of metanitroacetanilide and parabromacetanilide in the absence of hydrobromic acid was unsuccessful. When solvents which are attacked by bromine — such as chloroform, glacial acetic acid, or ligroïn — were used, perhalides were formed. The following compounds are described: From metanitroacetanilide the salt $(C_6H_4.NO_2.NHCOCH_3)_2HBr$, which forms perbromides containing three, five, and seven atoms of bromine; from para-

bromacetanilide an analogous bromide which takes up two and four atoms of bromine; and from acetanilide the iodide $(C_6H_5.NHCOCH_3)_2HI$, which gives a tri- and pentiodide.

The Action of the Halogens on the Methylamines. By Ira Remsen and James F. Norris. *Am. Chem. J.*, 18, 90–95. — When dry trimethylamine is passed into bromine the precipitate which is formed has the composition $(CH_3)_3N.Br_2$. The same compound is formed when the hydrobromide of trimethylamine is dissolved in concentrated hydrobromic acid and treated with bromine. The addition-product is soluble in absolute alcohol, insoluble in ether, and crystallizes from a mixture of the two in light yellow needles. Water liberates one atom of bromine. Dimethylamine forms an analogous compound, $(CH_3)_2HN.Br_2$, with similar properties. Trimethylamine precipitates from an alcoholic solution of iodine the addition-product $(CH_3)_3N.I_2$, a light yellow powder, which gradually changes to a dark brown viscous liquid. It is insoluble in water, and is decomposed by dilute acids with the liberation of all of the iodine. When the chlorides of dimethyl- or trimethylamine are treated with bromine, compounds containing both halogens result. No addition-products of methylamine were found.

On the Oxidation of Diacetyl. By Harry F. Keller and Philip Maas. *J. Franklin Inst.*, 141, 224–227. — Diacetyl, $CH_3CO.COCH_3$, was oxidized with a 3 per cent. solution of hydrogen peroxide, and the resulting acid solution neutralized with barium carbonate. The yield of barium acetate was quantitative. Potassium permanganate effected the same kind of oxidation, while with nitric acid the chief product was oxalic acid.

The Qualitative Examination of Acetanilid. By Charles Platt. *J. Am. Chem. Soc.*, 18, 142–146. — Acetanilid is soluble in about 190 parts of water and in 5 parts of alcohol at 15°, in 18 parts of boiling water, and in about $\frac{1}{10}$ part of boiling alcohol. Its deportment with a number of reagents is described. A number of the reactions described are hardly characteristic; for example, "a solution in concentrated sulphuric acid is turned a dark green on addition of a few drops of potassium chromate," and "a solution of acetanilid in hydrochloric acid, diluted, and treated with a weak solution of chromic acid gives a yellowish green coloration, which gradually turns to a dark green. Potassium hydroxide produces a blue precipitate in this solution."

Action of Acid Amides on Benzoin. By Alfred Newlin Seal. *J. Am. Chem. Soc.*, 18, 101–119. — Acid amides heated with benzoin in alcoholic solution do not yield condensation-products, but break down with the liberation of ammonia and the formation of an ester with the alcohol. The ammonia then reacts with the benzoin in the way already studied by others. The reaction takes place with the greatest ease with malonamide, and only with great difficulty and at high temperatures with benzamide. In every case tetraphenylazine is a constant product, while benzoinam and benzoinidam are produced at lower temperatures, lophine at higher. The presence of alcohol is not necessary to induce the breaking down of the amide. An unsuccessful attempt was made to chlorinate and brominate tetraphenylazine. The base obtained by the reduction of its tetranitro derivative is soluble in alcohol, but could not be obtained in crystalline condition. When heated it darkens and melts above 260° with decomposition. Its hydrochloride is a reddish brown transparent mass, which melts at about 140°.

On the Action of Aluminum Chloride on Saturated Hydrocarbons. By HOMER W. HILLYER. *Trans. Wis. Acad. Sci.*, 10, 367–369. — Attention is called to the fact that petroleum-ether cannot be used as a diluent in the Friedel and Craft reaction, as it is acted on by aluminum chloride rapidly at 40°–50°. Hydrochloric acid and combustible gases are evolved and a tarry mass remains, which is decomposed by water with evolution of heat and formation of an oil which cannot be distilled without decomposition. Pure heptane reacted in the same way.

On the Classification of Carbon-Compounds. By EDWARD KREMERS. *Trans. Wis. Acad. Sci.*, 10, 310–326. — A paper of theoretical interest, which cannot be reviewed briefly.

Notes on a Few Pyridine Alkyl Iodides. By ALBERT B. PRESCOTT. *J. Am. Chem. Soc.*, 18, 91–96. — Pyridinemethyliodide, slightly deliquescent, pencil-shaped crystals, melting at 117°, was made by cautiously adding methyliodide to pyridine in a flask provided with a return condenser. An analogous addition-product containing ethyliodide was formed by shaking the substances together at the temperature of the room — colorless plates, melting point 90.5°. To make the propyl and isopropyl compounds an excess of the alkyliodides was heated in a sealed tube with pyridine for an hour at 130°. The melting point of the former is 52°–53°; of the latter, 114°–115°. From a table of the melting points of the pyridinealkyliodides it appears that, comparing homologues and again comparing isomers, the melting points of the addition-products fall as the boiling points of the free alkyliodides rise. The same reverse ratio appears among picolinealkyliodides. Comparing the addition-products of two homologous bases with the same alkyliodide, it is found that the melting point rises as the boiling point of the tertiary base rises.

Pyridine Alkyl Hydroxides. By A. B. PRESCOTT AND S. H. BAER. *J. Am. Chem. Soc.*, 18, 247–251. — By shaking pyridinepropyliodide with moist silver oxide the free base was obtained, which precipitates salts of lead, mercury, copper, iron, aluminum, chromium, cobalt, and nickel, an excess of the hydroxide dissolving the precipitates of lead and aluminum. Its solution gives alkaline reactions with litmus, phenolphalein, brazil wood, cochineal, hematoxylin, and methylorange. By evaporation of a solution of the hydroxide in air, hydrogen, or vacuum a considerable proportion of the base is left as a dark solid mixed with decomposition-products not yet studied. Pyridineisopropylhydroxide was formed and possessed the same properties. Its normal carbonate sulphate and double salt with platinum chloride are easily prepared and preserved.

Dipyridine Trimethylene Dibromide and a Study of Certain Additive Reactions of Organic Bases. By R. F. FLINTERMANN AND A. B. PRESCOTT. *J. Am. Chem. Soc.*, 18, 28–35. — The article is a discussion of the addition-products of the organic bases, principally the tertiary amines, with halogen substituted hydrocarbons. The only new compound described is dipyridinetrimethylenedibromide, which was shown to have the formula $C_5H_5N\langle \begin{matrix} CH_2.CH_2.CH_2 \\ Br \qquad\quad Br \end{matrix} \rangle NC_5H_5$ by a molecular weight determination, using phenol as solvent. No addition-products of pyridine with propylenebromide, $CH_3.CHBr.CH_2Br$, or ethylidinechloride could be obtained.

Analytical Chemistry.

Ultimate Analysis.

H. P. Talbot, Reviewer.

On the Determination of Carbon Dioxide by Absorption. By H. Heidenhain. *J. Am. Chem. Soc.*, **18**, 1–6. — The discussion relates to the determination of carbon dioxide by absorption in soda-lime. Two absorption tubes are found necessary, the first of which is mainly filled with soda-lime, to which a small amount of calcium chloride is added, while the second contains the two substances named in equal proportions. The interchange of tubes for a second analysis, as recommended by Fresenius, was not found advantageous. Even in blank analyses the second tube was found to gain about 5 milligrams, and it was continuously used until the total gain amounted to $\frac{1}{10}$ of a gram, when it was refilled. Twenty grams of soda-lime will absorb 1 gram of the carbon dioxide. The author lays great stress on the rate of aspiration, and recommends that it, as well as the volume of air required, be determined by careful experiment for the apparatus used. The best rate seemed to be about 10 cc. per minute during the absorption of the main quantity of the carbon dioxide, to be then increased to 20 cc. per minute. A sketch of the apparatus used by the author appears with the article. In the opinion of the reviewer, the use of potassium hydroxide solution as an absorbent for the carbon dioxide offers, in general, greater security than the use of soda-lime, which he has found to be somewhat erratic in its behavior as regards loss of moisture.

A Gravimetric Method of Estimating Phosphoric Acid as Ammonium Phosphomolybdate. By Thomas S. Gladding. *J. Am. Chem. Soc.*, **18**, 23–27. — The ammonium phosphomolybdate is precipitated as follows: To the solution of the phosphoric acid, having a volume of 25–50 cc., ammonia (0.90 sp. gr.) is added (25 cc.) and nitric acid (1.42 sp. gr.) to acidity. The solution is placed in a water bath at 50° C., and a 10 per cent. molybdate solution is added from a burette at the rate of three drops per second, with constant stirring, until 10 cc. are added in excess. The solution is allowed to stand ten minutes in the bath and then filtered on a tared filter, washed with dilute nitric acid (1 : 100), and dried at 105° C. It is claimed that this precipitate is free from occluded salts and iron, and that when dried at 105° C. it possesses the composition indicated by the symbol, $24MoO_3.P_2O_5.3(NH_4)_2O + 24MoO_3.P_2O_5.2(NH_4)_2O.H_2O + 5Aq$. This procedure may be applied to citrate soluble phosphoric acid. The results communicated are concordant, to a high degree, with those obtained by standard methods, and from the analyses presented one cannot perhaps question the symbol assigned to the yellow precipitate as obtained by the author. Whether this symbol is, "without any doubt, the correct one," and therefore to supersede all others, may perhaps be open to argument. (Compare *Tech. Quart.*, **8**, 398.)

A Proposed Schedule of Allowable Difference and of Probable Limit of Accuracy in Quantitative Analyses of Metallurgical Materials. By E. D. Campbell. *J. Am. Chem. Soc.*, **18**, 35–37. — The author presents a table based upon a careful consideration of the usual errors of analysis, the commercial requirements of accuracy, and the unavoidable sources

of error, which includes the constituents usually determined in irons, steels, ores, coal, and cokes. From it the allowable difference in the analyses of two individuals working upon the same material, and also the probable minimum error which may be hoped for, can be calculated for each analysis. For example, two chemists working upon a steel containing 0.076 per cent. phosphorus might reasonably differ by ± 0.00352 per cent., and the error could not probably be reduced below 0.00058 per cent.

An Electrolytic Method for the Determination of Mercury in Cinnabar. By W. B. Rising and Victor Lenher. *J. Am. Chem. Soc.*, 18, 96–98. — The use of hydrobromic acid as a solvent for the mercuric sulphide is recommended, since solution takes place promptly and at a low temperature, without loss of mercury. The cinnabar is treated with a slight excess of 20 per cent. hydrobromic acid at a boiling temperature. The excess of acid is neutralized with potassium hydroxide, an excess of potassium cyanide is added, and the solution subjected to the action of a current of density 0.025 ampere per 100 square centimeters.

The Electrolytic Estimation of Mercury. By Edgar F. Smith and Daniel L. Wallace. *J. Am. Chem. Soc.*, 18, 169–170. — The authors state that the determination of mercury in a sample of cinnabar may be more rapidly accomplished by electrolytic deposition from a sodium sulphide solution than from a cyanide solution. (Compare preceding abstract.) The mineral is treated directly with 20–25 cc. of sodium sulphide solution (sp. gr. 1.22), which is diluted to 125 cc. and electrolyzed at 70° C. with a current of density 0.12 ampere per 100 square centimeters. The precipitation was complete in three hours. Care should be taken to avoid evaporation of the solution, that no mercuric sulphide may form.

The Precipitation of Phosphomolybdate in Steel Analysis. By George Auchy. *J. Am. Chem. Soc.*, 18, 170–174. — The author finds that when a molybdate solution prepared according to the formula of Blair and Whitfield (*Tech. Quart.*, p. 398) has been used for the precipitation of phosphorus, a secondary deposit of the phosphomolybdate takes place after the addition of the wash water. This is ascribed to the lesser quantity of ammonium nitrate present in the new solution, and to the dilution by the wash water. The use of 100 cc. of nitric acid (sp. gr. 1.13) is recommended, with the addition of 15 cc. of strong ammonia, diluted with 50 cc. of cold water just before precipitation, to form additional ammonium nitrate. The Blair and Whitfield solution is commended as a stable solution. — The author does not consider it necessary to note the exact temperature at the time of precipitation, and quotes authorities to show that the precipitation should be complete at any temperature between 25° and 85° C.

Indirect Analysis. By Edward K. Landis. *J. Am. Chem. Soc.*, 18, 182–188. — The paper contains algebraic solutions of certain problems arising in the course of indirect analyses.

Method for the Determination of Carbon in Steel. By Andrew A. Blair. *J. Am. Chem. Soc.*, 18, 223–227. — The method presented is that in use in the steel works laboratories in the eastern part of France. The steel (1 gram) is treated with cupric sulphate until a superficial deposit of copper

has taken place, and then with a mixture of chromic, sulphuric, and phosphoric acids at a boiling temperature. The liberated gases are measured and the carbon dioxide removed by absorption in caustic potash, its volume being determined by difference. For a description of the somewhat elaborate apparatus reference must be made to the original paper.

Remarks on Mr. Auchy's Paper on the Volumetric Determination of Manganese. By George C. Stone. *J. Am. Chem. Soc.*, **18**, 228–230. — The author prefers the Deshay method to that of Williams or Volhard for very small quantities of manganese, and gives the preference to the last named method for general work. A quantity of the material containing 0.05–0.15 gram manganese is dissolved in a slight excess of nitric acid (sp. gr. 1.10) or, if an ore or cinder, in hydrochloric acid and a little potassium chlorate. The solution is washed into a half-liter flask, the iron precipitated with zinc oxide, and an aliquot portion taken for analysis. The titration is completed in a casserole. The use of either nitric, hydrochloric, or sulphuric acid appears to the author to be permissible, provided the iron be oxidized. It is claimed that commercial zinc oxide may be safely employed; but the experience of the reviewer does not point in the same direction, as he has found considerable difficulty in procuring a sample of zinc oxide, even one supposed to be pure, with the exception of the specially prepared oxide now on the market for use in manganese determinations, which did not affect the permanganate solution.

The Iodometric Determination of Selenious and Selenic Acids. By F. A. Gooch and A. W. Peirce. *Am. J. Sci.*, **151**, 31–34. — If arsenic acid be added in excess to a solution of potassium iodide, acidified with sulphuric acid, and the mixture distilled, the iodine is completely liberated and expelled, with a corresponding reduction of the arsenic acid to arsenious acid. If selenious acid be also present, that is first reduced, and the amount of arsenious acid formed is proportionately less. The potassium iodide is added in slight excess over the quantity required to react with the selenious acid, the exact amount of the iodide being noted. Dihydrogen potassium arseniate (2 grams) is then added and 20 cc. of sulphuric acid. The solution is boiled, avoiding mechanical loss, until the volume is reduced from 100 cc. to 35 cc., after which the residual liquid is made alkaline with acid potassium carbonate and the arsenious acid titrated with iodine. Selenic acid must first be reduced to selenious acid, which is accomplished by potassium bromide and sulphuric acid, as arsenious bromide is non-volatile. The results obtained by this process are very satisfactory.

On the Interaction of Chromic and Arsenious Acids. By Philip E. Browning. *Am. J. Sci.*, **151**, 35–37. — The author finds that chromic acid may be determined, with the aid of Kessler's reaction (*Pogg. Ann.*, **95**, 204), with a fair degree of accuracy. The procedure is the following: The measured solution of the chromate is mixed with dilute hydrochloric or sulphuric acid, and an excess of arsenious acid is added to the cold solution. The action is promptly completed, and an excess of sodium bicarbonate is added and a standard iodine solution in slight excess. The whole is allowed to stand for a half hour, after which the excess of iodine is determined by further addition of arsenious acid, using starch as indicator. The addition of Rochelle salts prevents the precipitation of the chromium by the bicarbonate, but interferes somewhat with the final end-point.

A Method for the Separation of Selenium from Tellurium Based Upon the Difference in Volatility of the Bromides. By F. A. Gooch and A. W. Peirce. *Am. J. Sci.*, 151, 181–185. — It was found that when aqueous solutions of selenious acid, phosphoric acid, and sodium chloride are submitted to distillation, and the boiling is pressed beyond the point at which (in the presence of the bromides) the solution begins to be colored, selenium appears in traces in the tube leading from the flask, and the distillate liberates iodine, indicating a partial decomposition of the selenium compounds of the halogens. From the mixture containing the sodium chloride only a partial volatilization of the selenium was accomplished, while with the bromide a complete transfer of the selenium to the distillate was possible, affording a means of separation from such elements as tellurium, of which the bromide is not volatile. The distillation took place in a Voit flask, connected with a second flask containing 10 cc. of water, and followed by a Drexel bottle, with a Will and Varrentrapp bulb, both charged with potassium iodide solution. To the mixture of selenium and tellurium compounds 20 cc. of syrupy phosphoric acid (sp. gr. 1.70), 1 gram of potassium bromide, and water enough to bring the total volume up to 50 cc. are added. Carbon dioxide is passed through the flasks, and the solution boiled until the volume is reduced to 15 cc. After cooling, the first Voit flask is removed; 1 gram of potassium iodide and 5 cc. of hydrochloric acid are added to the contents of the second Voit flask; carbon dioxide is again passed through and boiling continued for ten minutes. At the end of that time all the iodine has collected in the Drexel bottle, together with the small amount set free by escaping bromine during the first distillation. The amount of free iodine may be determined by titration with sodium thiosulphate, and is a measure of the selenious acid present. It was found necessary to cover the tube leading from the distilling flask with asbestos and warm gently with a flame toward the close of the distillation, in order to remove all the selenium bromides. The separation from the tellurium is complete and satisfactory.

A Method for the Standardization of Potassium Permanganate and Sulphuric Acid. By H. N. Morse and A. D. Chambers. *Am. Chem. J.*, 18, 236–238. — The potassium permanganate solution is allowed to react with neutral hydrogen peroxide solution, in the presence of a measured excess of standard sulphuric acid, until about 50 cc. of the permanganate solution have been consumed. The unused excess of the sulphuric acid is then determined by titration with ammonia, litmus acting as indicator. From these data the value of the permanganate solution may be determined, or, if the value of the permanganate solution be known, that of the sulphuric acid solution may be calculated. The results presented agree well with those obtained by standard methods.

The Determination of Bismuth in Refined Lead and in Lead Bullion. By L. G. Eakins. *Proc. Col. Sci. Soc.*, Feb. 4, 1895. — For refined lead the method of analysis is essentially the same as given by Fresenius (*Ztschr. Anal. Chem.*, 8, 148), with the necessary precautions which the author has found most advantageous for the complete separation of bismuth from the other metals. The process for lead bullion is only slightly modified. Attempts were made to precipitate the silver as silver chloride along with the lead sulphate, but bismuth oxychloride was sometimes precipitated, so that it

was necessary to exclude the use of chlorides from the procedure. The solutions, which have been evaporated until fumes of sulphuric acid are given off, should not be allowed to stand for any length of time, as there is a tendency for the bismuth to separate in a form which subsequent dilution and boiling fail to redissolve. It was found that in ores carrying lead to the extent of 10 per cent., or over, practically all of the bismuth is found in the lead button in the assay, so that these buttons can be used for the determination of bismuth in ores by the usual method.

Methods for the Analysis of Ores, Pig Iron, and Steel in Use in the Laboratory of the Carnegie Steel Company, at Homestead, Pa. By JOHN S. UNGER. **Methods for the Analysis of Iron Ores, Pig Iron, and Steel in Use at the Laboratory of the Monongahela Furnace, McKeesport, Pa.** By FREDERICK CRABTREE. **Methods for the Analysis of Ores, Pig Iron, and Steel in Use in the Chemical Laboratory of the Junction Iron and Steel Company, Steubenville, Ohio.** By JOSEPH M. WILSON. **Methods for the Analysis of Ores, Pig Iron, and Steel in Use in the Laboratory of the Carnegie Steel Company, Lucy Furnace, Pittsburg, Pa.** By ROBERT MILLER. — These papers are published as separate pamphlets in connection with the *Proc. Eng. Soc. W. Pa.*, 1896, and have been prepared in response to a circular issued by the chemical section of the society, having for its object the collection of the methods of analysis in use in the various iron and steel works laboratories of the region. The sub-committee having the matter in charge presents the papers as offered to them without comment or discussion. The methods detailed are supposed to be those in common use, on which the commercial transactions of the firm are based. When the procedure is identical with one previously published only reference to such method is made, but desirable modifications are noted. No brief review of these papers is practicable.

A. H. GILL, REVIEWER.

On the Determination of Sulphur in Illuminating Gas and in Coal. By CHARLES F. MABERY. *Am. Chem. J.*, **18**, 207. — The author reviews the work which has been done upon this subject, and finally employs the Sauer method of combustion of the gas with air in a constricted combustion tube, absorbing the products of combustion in centinormal sodium hydrate. This is contained in a large U tube, filled for at least 8 cm. with broken glass. The oxidation of the gas is found to be practically complete, as tests with hydrogen peroxide show. Furthermore, the alkali in the first tube retains all the oxides of sulphur without difficulty. For coal the same process is employed, using deci- or quinquinormal sodium hydrate. The method for gas analysis does not, in the reviewer's opinion, lend itself to the purposes of the inspector as well as that of Hinman, which makes use of a modified Drehschmidt apparatus.

On the Quantitative Determination of Hydrogen by Means of Palladious Chloride. By E. D. CAMPBELL AND E. B. HART. *Am. Chem. J.*, **18**, 294. — Following the suggestion of Phillips, the authors use for the absorption of hydrogen a 1 per cent. solution of palladious chloride in a Hempel pipette, which can be dismounted and heated in a water bath to 50° over night. The absorption is shown by seven experiments to be complete. A

2 per cent. solution has no advantage over a 1 per cent. Strongly acid solutions retard the absorption. The reduced palladium is redissolved and the solution diluted to the proper strength; 100 cc. are used to fill a pipette, and this amount absorbs about 65 cc. hydrogen.

Proximate Analysis.

F. H. THORP, REVIEWER.

Technical Analysis of Asphaltum. BY LAURA A. LINTON. *J. Am. Chem. Soc.*, **18**, 275–283. — Some changes are suggested in the methods of analysis previously described (*J. Am. Chem. Soc.*, **16**, 809). The usual method of determining moisture in asphaltum by drying at 100° is shown to be defective, an error resulting from the loss of volatile matter other than water contained in the petrolene. It is further demonstrated that the oxidation of the asphaltum does not take place below 100° C., and that the moisture may be eliminated at 50° C., and that samples should be air-dried to a constant weight before weighing out the test portion to be treated with solvents. Another change recommended is to weigh directly into the filter papers and to do the digestion in separatory funnels. Care must be taken that the solution in the funnels does not become too concentrated before it is drawn off, as the petrolene may precipitate and some of it adhere to the outside of the filter paper. It is well to draw off the petroleum-ether every few minutes until most of the petrolene is extracted. After so doing the time of digestion may be extended to several hours. On fractionating the asphaltene, two portions were obtained — one soluble in boiling turpentine, and the other in chloroform. The process is very tedious, and requires several days. It is complete when the dried residue from the turpentine extraction is a loose brown powder without coherence. The portion soluble in boiling turpentine is a black, semi-liquid substance resembling tar, and probably melting below 100° C. "Aged" varieties of asphaltum contain a larger percentage of asphaltene, and the turpentine soluble fraction is a smaller proportion of the total bitumen, while the chloroform soluble fraction is larger. From the physical differences between the turpentine and the chloroform fractions the author is of the opinion that chemical differences also exist. She does not consider the use of carbon disulphide so satisfactory as chloroform. Analyses of twelve samples are tabulated, and a discussion by members of the society is given.

On the Use of Acetone in the Technical Analysis of Asphaltum. BY S. F. PECKHAM. *J. Franklin Inst.*, **141**, 219–223. — In this paper the author takes issue with Sadtler (*Tech. Quart.*, **8**, 410) concerning the use of acetone in place of petroleum-ether as a solvent in the analysis of asphaltum. He advocates the theory that solution should be considered as a chemical reaction, and consequently as an index of chemical properties. Duplicate analyses were made of Trinidad and Egyptian asphaltum and of a maltha, with acetone and with petroleum-ether as solvents. From his results the author concludes that acetone is not an equivalent for petroleum-ether in technical analyses of asphaltum. Its solvent properties on pure bitumen are unlike those of petroleum-ether, and from a complex pitch it dissolves constituents which are not bitumen. He regards its action as approximating that of the alcohols on bitumen.

G. W. ROLFE, REVIEWER.

On the Estimation of Levulose in Honeys and Other Substances. BY H. W. WILEY. *J. Am. Chem. Soc.*, **18**, 81–90. — The author has elaborated the method of Chandler and Ricketts for determining the influence of optically active bodies other than invert-sugar, and applied it to the determination of levulose. This method depends on the fact that the optical rotation of levulose decreases as the temperature is increased. The author has proved that this variant of the rotation is in exact proportion to the increase of temperature between 0° and 88°, the point at which the opposite rotations of dextrose and levulose are balanced, and gives the deviation in reading of 1 gram of levulose in 100 cubic centimeters per degree, centigrade as .0357° for the Ventzke scale or $(.01256)_D$. There is an excellent description of the apparatus, which in design of tube resembles that recently described by Landolt; also a clear exposition of the philosophy of the process and details of manipulation, which will make the paper valuable to the technical analyst especially. As is intimated, in certain cases a few minor corrections will have to be made for influence of acids, etc., especially if commercial glucose is present — a common adulterant. It will be noted that the author gives the factor 0.3468 for converting degrees, Ventzke to degrees of angular rotation for yellow light in the case of cane-sugar solutions, while recent German work gives the figure 0.344.

Note on the Use of Acetylene Gas as an Illuminant for Polariscopic Work. BY H. W. WILEY. *J. Am. Chem. Soc.*, **18**, 179–182. — The experiments of the author in reading standard quartz plates, and especially dark molasses solutions, show "that the acetylene light is perfectly reliable for polarizing purposes, that it produces an intense degree of illumination, permitting of a very delicate distinction between shadow and illuminated portions of the field of vision, and permits the reading of solutions so highly colored as to be perfectly opaque to the ordinary sources of light." The rate of gas consumption was 15 liters per hour, measured at 18° C. One kilo of the carbide furnished a little over 226 liters of gas.

On the Inversion of Sugar by Salts. BY J. H. LONG. *J. Am. Chem. Soc.*, **18**, 120–130. — The author has found that sugar syrups containing "heavy salts" are gradually inverted. He gives the results of a series of experiments with several cane-sugar solutions of 50 grams per 100 cubic centimeters, containing respectively ferrous iodide, chloride, bromide, and sulphate, ferrous ammonium sulphate, zinc sulphate, manganous chloride, manganous sulphate, potash alum, lead nitrate, lead chloride, cadmium chloride, and mercuric chloride. Most of the inversions were made at 100° C. The rates of inversion were found to be conformable to the Wilhelmy-Ostwald formula.

A. H. GILL, REVIEWER.

The Determination of Solid Fat in Artificial Mixtures of Vegetable and Animal Fats and Oils. BY J. H. WAINWRIGHT. *J. Am. Chem. Soc.*, **18**, 259. — The method, although not based upon chemical principles, yet gives results in practice within about 1½ per cent. of the correct amount. It consists in pressing out the solid fat from the cooled mixture, and, although rough, its results surpass in accuracy the scientific methods. 150 grams of the sample are melted in a beaker in boiling water, kept so for an hour, and

then allowed to cool over night at the ordinary room temperature. The solid fat having separated, it is thoroughly mixed, 50 grams weighed out, wrapped carefully in a double thickness of Canton flannel, and pressed very gradually, especially at first, in a small screw-press (Osborne's patent beef press) for at least one hour, the pressure being finally as great as is possible. The contents of the press are then removed, the cake of stearin separated from the flannel and weighed. The method would seem especially applicable to the various lard substitutes.

Determination of the Heat of Bromination in Oils. By H. W. Wiley. *J. Am. Chem. Soc.*, **18**, 378. — Hehner and Mitchell propose to measure the heat evolved by the action of bromine upon an oil after the manner of the Maumené test. Their method of execution left, however, some improvements to be desired, which the present article describes. The reaction takes place in a test-tube fitted air-tight in a calcium chloride drying jar, from which the air is sucked out; the thermometer is read to tenths of a degree. Ten grams of the fat are dissolved in 50 cc. chloroform, 5 cc. measured into the test-tube, and 4 cc. of a solution of bromine in chloroform 1 : 4 are then added, the thermometer inserted, and the highest point noted, with the help of a lens. The reaction is complete in two minutes, the contents of the tube poured out, and the tube allowed to air out for half an hour and the test repeated. At least four measurements should be taken with each sample, and the oil and bromine solutions should be at the same temperature. Stirring is disadvantageous, causing a loss of heat. Olive oil gave in carbon tetrachloride a rise of temperature of 18.20; cottonseed, 24.9; sunflower-seed, 27.6. The author calls attention to the fact that carbon tetrachloride is a better solvent to use, as it is indifferent to bromine, while chloroform forms $CBrCl_3$, making the heats of bromination somewhat higher.

Method of Determining Proportions of Oil Pigment and Moisture or Deficiency of Hydration in Freight Car Color. By C. B. Dudley and F. N. Pease. *Am. Eng. R.R. J.*, 70, 54. — The moisture must not exceed 2 per cent., the oil may vary between 23 and 27 per cent. and must be pure raw linseed, and the pigment makes up the balance, of which 20 per cent. must be Fe_2O_3; the remainder may be gypsum, silica, kaolin, soapstone, or asbestine, the two former being preferred. The process consists in extracting the pigment, usually 5 grams, with 88° gasolene in an Erlenmeyer flask, allowing the solid matter to settle, drying and weighing the residue. Minute notes and precautions accompany the article.

E. H. Richards, Reviewer.

Notes upon the Determination of Nitrites in Potable Water. By A. H. Gill and H. A. Richardson. *J. Am. Chem. Soc.*, **98**, 21–23. — In view of the increasing importance attached to the presence of nitrites in water as an indication of pollution, this discussion of methods of determination is welcome.

The Coloring-Matter of Natural Waters, its Source, Composition, and Quantitative Measurements. By Ellen H. Richards and J. W. Ellms. *J. Am. Chem. Soc.*, **18**, 68–81. — The increasing use of surface waters for city supplies has rendered the question of color one of importance. It has been proved that in most cases this coloring matter is not detrimental to health, and it becomes important to eliminate from an analysis the numer-

ical results due to this coloring matter before deciding upon the quality of a supply. The instrument devised by Joseph W. Lovibond, of Salisbury, England, called the tintometer, has been used in measuring the quantity of color in water. The paper is accompanied by charts and tables.

The Measurement of the Colors of Natural Waters. By ALLEN HAZEN. *J. Am. Chem. Soc.*, **18**, 264–275. — The author discusses at length the different methods which have been used for the determination of depth of color in water, with especial reference to the use of the platinum standard.

Note on the Microscopic Detection of Beef Fat in Lard. By THOMAS S. GLADDING. *J. Am. Chem. Soc.*, **18**, 189. — The author crystallizes the stearin from an ether solution preparatory to the examination.

Chemical vs. Bacteriological Examination of Potable Water. By W. P. MASON. *J. Am. Chem. Soc.*, **18**, 166–168. — Professor Mason gives a timely caution in regard to the danger of placing too great reliance on the popular method of testing for sewage pollution in potable water. The possibilities of modern chemical analysis are hardly appreciated outside of a few laboratories, and it is quite time for the chemist to call attention to the change in his position in regard to the interpretation of water analyses.

Milk Testing. *Bull. No. 101, Ontario Agr. College and Experimental Farm*, 1–30. — The notes from the Dairy School contain very clear and concise directions for the testing of milk, cream, and cheese, and also give the precautions to be taken in order to secure accurate results.

Index to the Literature on the Detection and Estimation of Fusel Oil in Spirits. By W. D. BIGELOW. *J. Am. Chem. Soc.*, **18**, 397–402. — Nearly fifty names of authors and about three hundred references indicate the amount of work which has been done on this subject.

The Use of the Calorimeter in Detecting Adulterations of Butter and Lard. By E. A. SCHWEINITZ AND JAMES A. EMERY. *J. Am. Chem. Soc.*, **18**, 174–179. — A new method, which may be useful in connection with others for the determination of certain fats in mixtures, is described. The combustion calories yielded by the different pure fats seem to be an indication of their chemical composition, and thus to furnish additional evidence in doubtful cases.

Assaying.

H. O. HOFMAN, REVIEWER.

Notes on the Assay of Rich Silver Ores. By E. H. MILLER AND C. H. FULTON. *School Mines Quart.*, **17**, 160–170. This subject, which has lately been much discussed by Mason and Bowman, Dewey, Stetefeldt, Furman, Rose, and others, is here taken up again, the aim being to show how much of the loss is due to slagging in the crucible and in the scorifier, and how much to separating silver (gold) from lead in the cupel. Two ores were assayed, one a cerussite rich in silver, but low in gold; the other an argentite rich both in silver and gold. Four tables contain the results obtained, and their tendency is to give the crucible assay a better showing than the scorifier.

TECHNICAL CHEMISTRY.

F. H. THORP, REVIEWER.

The Artificial Production of Asphalt from Petroleum. BY CHARLES F. MABERY AND J. H. BYERLEY. *Am. Chem. J.*, 18, 141–150. — This is an account of an investigation of the products derived from the heavy residual oils left after the distillation of burning oils from crude petroleum. The first part of the paper is a *résumé* of the work of other investigators on the action of heat on the members of the paraffine series, and a consideration of the conditions under which "cracking" occurs. An abstract of a paper to be published by C. F. Mabery and O. C. Dunn on the bromine absorption of petroleum distillates is also included. The major part of the paper reviewed here is devoted to Byerley's method of distillation of the residuum of petroleum. This material, having a specific gravity between 25° and 28° Bè, is subjected to very slow distillation in a "cheese-box" still of 150 barrels capacity, and having "five vertical iron pipes, one and one half inches in diameter, extending to within a few inches of the bottom of the still," through which air is forced into the hot tar. The temperature is controlled by means of a pyrometer placed in the tar, and the distillation proceeds at from 450° to 650° F. The distillate is a dark red oil, whose specific gravity ranges from 0.8393 to 0.8584, and it is separated into two portions, which are refined for burning oil. The distillation requires four or five days, according to the product desired. Too rapid distillation results in a small yield of asphalt of inferior grade. The effect of the air introduced is to produce partial oxidation, and by keeping the tar in constant motion serves to protect it from the destructive action of the hot still bottom. Four commercial products may be produced, viz., *liquid asphalt*, flowing at 25° C. and used to soften asphalt for roofing and paving; *roofing asphalt*, plastic at 20° C. and flowing at 135° C., used for roofing, for tar paper, and for insulators and telephone conduits; *paving asphalt*, very slightly compressible in the fingers at 20° and flowing at 165° C.; and *Byerlyte*, resembling natural Gilsonite, flowing at 260° C., completely soluble in carbon disulphide, and useful in making varnish. It is partially soluble in ligroïn and in petroleum naphtha. This method of distillation prevents the formation of coke in the still, and the oxidation effect of the air introduced consists chiefly in the removal of hydrogen to form water, very little oxygen combining with the oils. Ultimate analyses of the above products are given, and also some observations on the determination of sulphur and of nitrogen in these products and in Gilsonite. In a footnote the author refers to the method of sulphur determination proposed by himself (*Am. Chem. J.*, 16, 549), and declares that for accuracy and ease of manipulation no other method is its equal.

Notes on the Literature of Explosives. BY CHARLES E. MONROE. *Proc. U. S. Naval Inst.*, 21, 789–833. — This is a collection of reviews of current literature on explosives. The author gives considerable space to an abstract of a report by Mr. West Steever on the importation, use, transportation, and manufacture of explosives (*Ex. Doc. No. 181, 53d Congress*), and to the text of a proposed national enactment governing the same. He also includes an account of experiments made by Lieutenant Rodman and himself to demonstrate the efficiency of various systems of vault and safe construction in resisting the effects of explosives (*Ex. Doc. No. 20, U. S. Senate, 53d Congress*). Reviews of several articles in foreign publications are likewise included.

The Manufacture of Acetone and Acetone-Chloroform from Acetic Acid. By EDWARD R. SQUIBB. *Squibb's Ephemeris*, 4, 1743–1757; *J. Am. Chem. Soc.*, 18, 231–247. — The first part of this paper is devoted to the discussion of the history, properties, composition and methods of preparing acetone, and to the claims of the owners of a certain patent that the process described by the author in a paper read before the American Chemical Society in 1895, infringes said patent. He shows that the patentees declare barium acetate to be formed at a temperature at which it cannot exist. Furthermore, that by his process a barium or any other salt in the furnace is not essential to the formation of acetone from acetic acid. Test runs made with the furnace filled with pumice stone only demonstrated that acetone could be made from acetic acid directly; but in four cases impossible results were obtained, showing a decomposition of more than 100 per cent. of the acid used. These are supposed to be due to errors in the use of the hydrometer or in analysis. It seems to the reviewer that it would have been well to state the actual weights of crude acetone obtained in each run. The remainder of the paper is given to the consideration of the preparation of chloroform from acetone. The results and conclusions of early investigators are taken up, particular attention being given to the paper of Siemerling (*Archiv. d. Pharm.*, 54, 23), in which gross errors are pointed out. And it is further shown that the United States patent issued to G. Rumpf for "An Improvement in the Manufacture of Chloroform from Acetone" is based upon these false conclusions of Siemerling; for the patentee claims an "improvement" on the method of Watts, who got his data from Gmelin's *Handbuch der Chemie*, in which Siemerling's paper is quoted. The author relates some of his own experience in using the Siemerling process, and conclusively demonstrates the results obtained by the latter to be erroneous. Accepting the facts set forth in this paper, it is difficult to understand how this Rumpf patent could have been granted, and the claim made by its owners that it "secures to them the sole right to make chloroform from acetone in the United States" would seem preposterous.

Utilization of By-Products from Coke Ovens. By J. A. MONTGOMERY. *Proc. Ala. Ind. Sci. Soc.*, 5, 10–19. — An interesting paper on the Simon-Carves oven, and a prognostication of the advantages to be derived from its use in coking Alabama coals.

Alabama's Resources for the Manufacture of Portland Cement. By EUGENE A. SMITH. *Proc. Ala. Ind. Sci. Soc.*, 5, 44–51. — The paper contains a number of analyses of Alabama limestones and clays by J. W. Mallett and W. B. Phillips. The author inclines to the opinion that a good cement may be produced from these materials.

Cattle Poisoning by Nitrate of Potash. By N. S. MAYO. *Bull. No. 49, Exp. Sta. Kan. Agr. College.*

Slag Cement in Germany. *U. S. Consular Rep.*, 50, 224–232. — This article comprises four reports on the manufacture, use, and cost of slag cement in Germany. From these it would seem that the industry is nearly extinct in that country.

On Trinidad Pitch. By S. F. PECKHAM AND LAURA A. LINTON. *Am. J. Sci.*, 151, 193–207. — The authors first give an extended account of the

deposits in Trinidad, including a description of the natural pitch and the changes which it undergoes on exposure to sun and air. The natural pitch is soft and contains much gas and water, but these escape very rapidly on exposure, the pitch becoming hard and brittle. Twenty-seven samples were taken for analysis, which were dried at 50° to constant weight before analysis, and the results calculated on the weight of the dry sample. Water was not regarded as a constituent of the pitch, because of its varying amount in the same specimen. If dried at 100° loss of oils occurs. The dry sample was first extracted with petroleum-ether, 74° Bé, the residue dried at 100°, and weighed. The loss of weight was calculated as *petrolene.* The residue was then extracted with boiling turpentine, washed with ethylalcohol, dried, weighed, and the loss noted. This residue was extracted with chloroform, dried, and again weighed. The combined loss by both extractions was estimated as *asphaltene.* This dried residue was then ignited to destroy the remaining organic matter, and the remaining mineral matter and sand were weighed. Petrolene and asphaltene were calculated together as "total bitumen," while "organic matter not bitumen" and "inorganic matter" were determined by the ignition. A discussion of the analyses follows, and it is shown that both petrolene and asphaltene are essential to the cement-forming character of the pitch, and taken together constitute the bitumen. The amount and quality of this bitumen, therefore, determine the character of the pitch. The authors consider "land pitch" as no less uniform in composition than "lake pitch." Complete analyses of the twenty-seven samples are then tabulated.

A. H. GILL, REVIEWER.

On Some Properties of Acetylene. BY FRANCIS C. PHILLIPS. *Proc. Eng. Soc. W. Pa.*, 12, 19. — The methods of preparation are discussed, also its uses as an illuminant and for producing a very hot flame with the blast lamp. An Argand burner cannot be used with it, as it smokes, and when lighted gives rise to dangerous explosions. The best results are obtained with a two-hole Bray burner, giving an equivalent of 208 candle power for 5 feet per hour. Using it in the blast lamp, a powerful blast is necessary. The heat is sufficient to melt platinum, volatilize silver, and melt hard glass combustion tubing of ⅛-inch bore when about 1 foot of acetylene is used per hour. The author calls attention to the fact that aluminium carbide yields methane upon moistening.

Another Chapter Concerning Studies in Calcic Carbide. BY M. P. WOOD. *Am. Gas Light J.*, 64, 242. — The author has continued his studies on the cost of preparation of acetylene. He finds that a horse power per year costs $10.32 when produced by water power, and $27.50 by steam power, with coal at 50 cents per ton. He finds that a ton of carbide costs theoretically, exclusive of profit, superintendence, and office expenses, $32; if allowance be made for losses, just about double. If these losses could be reduced, which is possible, it might be made for $20 per ton. The object of the company is apparently to sell *rights* to manufacture acetylene rather than to sell the *material* itself.

On the Composition of the Ohio and Canadian Sulphur Petroleums. BY CHARLES F. MABERY. *Am. Chem. J.*, 18, 43. — "The principal features of the Ohio petroleum are the following: 1. The crude oil is heavier

than the Pennsylvania and lighter than the Russian oil. In the quantities of the higher distillates and in its general properties it resembles more nearly the latter. 2. It differs from the other petroleums in the large amounts of sulphur compounds. . . . 3. It resembles the Pennsylvania oil in containing below 150° members of the series C_nH_{2n+2}, although in much smaller quantities. . . . 4. The aromatic hydrocarbons are here present in minute quantities, apparently much smaller than in other petroleums." Benzene, toluene, *m*- and *p*-xylene, hexahydroisoxylene have been identified. Canadian petroleum approaches the Russian oil more closely than does that from Ohio. It contains, in small quantities, the same aromatic hydrocarbons which are present in Ohio petroleum. The article concludes with a discussion of the origin of petroleum, especially with reference to the theory of destructive distillation, and points out that one of the difficulties is to find the source of heat adequate for the decomposition. Petroleum has been found in India issuing from a bed of tertiary oysters. Possibly the change to petroleum may have been accomplished by enormous pressure in the absence of air, and with this in mind the author is conducting some experiments to ascertain whether any such change takes place.

The Comparative Efficiency of West Virginia Coals. By James W. Paul. *Eng. Min. J.*, 61, 233. — The article calls attention to the fact that the West Virginia coals are of most excellent quality, and gives the physical properties, the fixed volatile matter, ash, and water of seventeen coals. In addition to this, calorimetric tests made with the Barrus calorimeter are given.

Investigations on American Petroleum. Chemistry of the Berea Grit Petroleum. By Charles F. Mabery and Orton C. Dunn. *Am. Chem. J.*, 18, 215–236. — The article deals first with the geological occurrence of the oil, and then gives the results of fractionating a large number of the oils from this region. Between 159° and 160° the fraction was so considerable as to indicate the presence of a single body. Such was found to be the case, and after fifty fractionations and purification with sulphuric acid the presence of decane was determined. Undecane and dodecane were also found to be present. Attention is especially called to the difficulty of removing water from the petroleums, sodium being required to accomplish it. When dry they reabsorb moisture greedily.

Metallurgical Chemistry.

H. O. Hofman, Reviewer.

Methods for the Collection of Metallurgic Dust and Fume. By M. W. Iles. *School Mines Quart.*, 17, 97–117. — A critical review of the different methods used, especially by silver-lead smelters, for settling out the coarse and fine particles of inorganic matter held in suspension by currents of air passing off from the various furnaces.

The Amalgamation of Rich Free Gold Ores. By F. Hille. *Eng. Min. J.*, 61, 136. — The paper is a description of small ball mills, of Lazlo pans, and of settlers used in Transylvania for amalgamating small charges of very rich gold ores. The apparatus appears well adapted for making laboratory milling tests.

Is Zinc Potassium Cyanide a Solvent for Gold? By E. B. W. and J. C. Wells. *Eng. Min. J.*, 61, 107 and 179. — E. B. W. argues that the conclusion drawn by Wells (*Tech. Quart*, 8, 438) that gold is soluble in zinc potassium cyanide is not warranted. He further says if the deposition of gold in the zinc boxes were attributed to electrolysis rather than to chemical precipitation much that is mysterious now would become clear. — Wells answers the criticism.

The Siemens-Halkse Cyanide Process. By the Editor. *Eng. Min. J.*, 61, 177. — The electrolytic deposition of gold from cyanide solutions has proved an economic failure, as with solutions of a normal degree of concentration the loss in cyanide is too great, and with the required very dilute solution the extraction of gold too low.

High-Silicon Iron in the Blast Furnace. By J. S. Kennedy. *Eng. Min. J.*, 61, 42. — Referring to a paper by Mathewson (*Tech. Quart.*, 8, 439) on this subject, the failure to give the manganese and sulphur of the pig or the composition of the slag is commented upon, as manganese aids in the blast furnace the production of high-silicon iron and protects the silicon in the cupola. In order to make manganese enter the pig, a hot furnace and a basic slag are essential. The author found no difficulty in making pig with from 4 to 5.5 per cent. silicon with a slag containing from 30 to 31 per cent. silica, provided there was enough manganese present for the pig to contain from 2 to 2.3 per cent. of it.

The Smelting of Titaniferous Ores. By A. J. Rossi. *Iron Age*, 57, 354–356, 464–469. — The paper is a record of experiments in smelting titaniferous iron ores in a small blast furnace, and a discussion of the subject as a whole and of the properties of the pig produced. Smelting titaniferous iron ores with 52 per cent. iron and 20 per cent. titanic acid presents no difficulties as long as silica and titanic acid, considered as acids, are combined with the bases alumina, lime, and magnesia in a manner to form a fusible titano-silicate slag, and an excess of fuel is avoided which might reduce titanic acid. The slags in which the ratio of oxygen of acids to the oxygen of bases did not exceed 4:3 proved the most fusible. Toward the end of the experiments the furnace ran exclusively on titaniferous iron ore. The following slag was made: SiO_2, 27.29; TiO_2, 17.48; Al_2O_3, 14.43; CaO, 22.71; MgO, 11.55; FeO, 4.30; the ratio of the oxygen of acids to that of bases being 4 : 3.50. — The consumption of coke with 62-per cent. Lake Superior ore was 2.15 tons per ton of pig, while that with Adirondack ore with 52 per cent. iron and 20 per cent. titanic acid was 1.99 tons. The high figures of coke consumption are due to the smallness of the three-tuyere experimental furnace, viz., height 20′; diameter of crucible 2′6″, of bosh 4′6″, of tunnel head 2′10″. The metal produced by the furnace is, of course, white; it runs low in titanium and silicon, often high in carbon (Si : trace — 0.36; Ti : 0.00 — 0.07; combined carbon : 2.8 — 3.0; graphitic carbon : 0.24 — 0.25). Its grain is close and fine, its fracture like steel in color and appearance; it is tough and hard, and shows a considerable depth of chill if cast in chilled molds.

Sulphur in Mild Steel. By F. E. Thompson. *Iron Age*, 57, 810–814.— At present there is no general process in use in the metallurgy of steel for the nearly complete removal of sulphur from pig iron. In the acid converter

and open-hearth furnace hardly any sulphur is eliminated; in the corresponding basic furnaces part of the sulphur is removed, the percentage depending on the total amount present and other conditions. Elimination is promoted by the presence of manganese and by agitation with lime, calcium chloride, calcium fluoride, and iron oxide. From basic steel sulphur is in part removed by manganiferous recarburizers. In ordinary mild structural steel, sulphur runs from 0.03 to 0.08 per cent.; fire-box (dead soft) steel, where sulphur and manganese must be low, can only be made from low-sulphur stock. — In following the results of sixty-four basic blows the author finds that steel with from 0.100 to 0.193 per cent. sulphur showed little, if any, red-shortness as long as manganese did not fall below 0.3 per cent., the common figure being from 0.4 to 0.5 per cent.; steel with from 0.036 to 0.103 per cent. sulphur was more or less red-short if manganese was low, viz., 0.045 — 0.225 per cent. In order to insure freedom from red-shortness, sulphur in steel ought to be below 0.05 per cent. if manganese falls below 0.200 per cent. — In working eleven hundred and forty-nine heats in the basic open-hearth furnace the sulphur in the pig, when melted, averaged 0.065 per cent.; in the resulting steel, 0.041 per cent., showing an elimination of 36.3 per cent. — The paper gives full data showing the effects of amount of ore added, of time, of initial amount of sulphur, and of additions of lime, fluorspar, ferromanganese, and manganese ore.

Geological and Mineralogical Chemistry.

W. O. Crosby, Reviewer.

The Association of the Gasteropod Genus Cyclora with Phosphate of Lime Deposits. By Arthur M. Miller. *Amer. Geologist*, 17, 74–76. — This is an attempt to determine the precise source of the phosphate of lime in the phosphatic limestones of Kentucky and Tennessee. Specimens from three different formations were examined. The plan was to analyze the rock as a whole, and then a weighed number of the fossil shells (Cyclora) known to be phosphatic. The analyses were made by Dr. Alfred M. Peter, with the following results:

	Cyclora Casts.		Rock.	
	P_2O_5.	$Ca_3(PO_4)_2$	P_2O_5.	$Ca_3(PO_4)_2$.
Tennessee (Devonian) Specimens,	28.0	61.0	11.90	26.0
Covington (Hudson River) "	22.7	49.5	.77	1.7
Lexington (Trenton) "	Very rich.		8–30	17.5–65.5

The conclusion is reached that the phosphate of lime was separated from the sea water by these minute marine gasteropods; that the rocks are phosphatic in proportion to their abundance; and that, as first announced by Safford, the phosphate of lime accumulation at the bottom of the sea is in inverse ratio to the rate of sedimentation.

On the Epidote from Huntington, Mass., and the Optical Properties of Epidote. By E. H. FORBES. *Am. J. Sci.*, 151, 26–30. — This mineral resembles zoisite, and its light color and the absence of the usual green of epidote indicated a low iron percentage, and suggested a chemical and optical investigation. The specific gravity averages 3.367, and the average of two accordant analyses gave: SiO_2, 37.99; Al_2O_3, 29.53; Fe_2O_3, 5.67; FeO, 0.53; MnO, 0.21; CaO, 23.85; H_2O, 2.04. This gives the ratios of silica, sesquioxides, protoxides, and water very nearly 6, 3, 4, 1, which, regarding the water as coming from hydroxyl, gives the usually accepted formula $H_2Ca_4Al_6Si_6O_{26}$, in which the calcium has been partly replaced by ferrous and the aluminum by ferric iron. The analysis is interesting as showing a remarkably low iron percentage for epidote. Comparing this analysis with others, it is found to be almost identical with that of a light-colored epidote from Zillerthal in Tyrol.

Notes on Sperrylite. By T. L. WALKER. *Am. J. Sci.*, 151, 110–112. — The author discusses the crystallization of sperrylite, and then cites facts to show that its natural matrix or host is chalcopyrite. In this connection it is noted that in all the copper-nickel mines of the Sudbury district traces of the metals of the platinum group are found, and that both the platinum metals and the nickel vary in amount directly as the copper. An analysis of matte from the Murray mine gave: Ni (with trace of Co), 48.22; Cu, 25.92; Fe, 2.94; S, 22.50; and traces of Au, Ag, Pt, Ir, Os, Rh, and Pd.

Fayalite from Rockport, Mass., and on the Optical Properties of the Chrysolite-Fayalite Group and of Monticellite. By S. L. PENFIELD AND E. H. FORBES. *Am. J. Sci.*, 151, 129–135. — The fayalite was found by J. H. Sears in the Rockport granite quarry, and formed a lenticular shell about 12 to 16 inches in diameter, filled on the inside with loose, earthy material, and enveloped by a layer of magnetite about 1 inch thick. Carefully freed from magnetite it gave as the average of two analyses, the average specific gravity being 4.318: SiO_2, 30.08; FeO, 68.12; MnO, 0.72; H_2O, 0.80. This makes the silica ratio 1 : 2, and indicates almost pure ferrous orthosilicate, Fe_2SiO_4, with only a trace of manganese and no magnesia, although a careful test was made for the latter. The small amount of water is considered as basic. Under the name hortonolite Professor Brush has described a member of the chrysolite-fayalite group found in an iron mine at Monroe, Orange County, New York, and characterized by its dark color and high iron percentage. In appearance it resembles the fayalite from Rockport. A new duplicate analysis (av. sp. gr. 4.038) gave the following average: SiO_2, 33.77; FeO, 47.26; MnO, 4.54; MgO, 13.88; H_2O, 0.48. The silica ratio is 1 : 1.95, or nearly 1 : 2, giving the formula $(FeMgMn)_2SiO_4$; and therefore the mineral holds an intermediate position between fayalite and the iron-rich chrysolites. The published analyses of chrysolite are so numerous that no new ones were made, but in order to make the investigation of this group more complete monticellite was included, the crystals from Magnet Cove, Arkansas (av. sp. gr. 3.035), giving the following average: SiO_2, 36.78; FeO, 4.75; MnO, 1.62; MgO, 21.60; CaO, 34.31; H_2O, 0.95. The ratio of SiO_2 : (MgFeMn)O : CaO = 1 : 1.02 : 1, giving the usually accepted formula $CaMgSiO_4$.

A Meteorite from Forsyth County, North Carolina. By E. A. DE SCHWEINITZ. *Am. J. Sci.*, 151, 208–209. — The description of this metallic

meteorite, which was brought to light by a plow and weighs about fifty pounds, is accompanied by an analysis showing: Fe, 94.90; S, 0.22; Ni, 4.18; Co, 0.33; P, trace.

On a New Alkali Hornblende and a Titaniferous Andradite from the Nepheline-Syenite of Dungannon, Hastings County, Ontario. By FRANK D. ADAMS AND B. J. HARRINGTON. *Am. J. Sci.*, 151, 210–218. — A description of the occurrence of these minerals and the method adopted for their separation is followed by the analyses and elaborate discussions of the same. So far as known no other hornblende containing so small a proportion of silica (34.184 per cent.) has been analyzed, but the small percentage of silica is explained by the large proportions of ferrous and ferric oxides (21.979 and 12.621 per cent., respectively).

On the Occurrence of Thaumasite at West Paterson, New Jersey. By S. L. PENFIELD AND J. H. PRATT. *Am. J. Sci.*, 151, 229–233. — In 1878 Baron von Nordenskiöld described a mineral from the copper mines of Areskuta, Jemtland, Sweden, which had the composition $CaSiO_3$,$CaCO_3$, $CaSO_4$,$14H_2O$, and to which the name thaumasite was given. That a mineral of such a remarkable composition was capable of existence was not accepted by all mineralogists; and Bertrand held that it was probably a mixture of calcite, gypsum, and wollastonite. Nordenskiöld succeeded, however, in answering all objections and establishing the validity of his species, though the proportion of water was changed by Widman to $15H_2O$. The present paper notes the occurrence of this unusually interesting mineral at Burger's quarry in West Paterson. Three analyses gave the following average: SiO_2, 9.26; CO_2, 6.82; SO_3, 13.44; CaO, 27.13; H_2O, 42.77; Na_2O, 0.39; K_2O, 0.18 = 99.99. The ratio of $SiO_2 : CO_2 : SO_3 : CaO : H_2O$ is very nearly 1 : 1 : 1 : 3 : 15, demanded by the formula $CaSiO_3$,$CaCO_3$,$CaSO_4$, $15H_2O$. The authors show that thirteen molecules of the water are to be regarded as water of crystallization and two molecules as constitutional. A discussion of the molecular structure follows.

Syenite-Gneiss (Leopard Rock) from the Apatite Region of Ottawa County, Canada. By C. H. GORDON. *Bull. Geol. Soc. Am.*, 7, 95–134. — The syenite-gneiss at the High Rock apatite mine is essentially a microcline, quartz, and pyroxene rock of igneous origin, presenting three more or less distinct structural phases or varieties, designated as coarse-grained, ellipsoidal (leopard rock), and streaked. The paper is a careful petrographic study of the gneiss in all its phases, but with special reference to the origin of the ellipsoidal structure. Analyses of the microcline and pyroxene made by Professor William Hoskins are given, and the general discussion takes account of all the modern theories of the chemico-physical as well as the mechanical differentiation of rocks.

Disintegration and Decomposition of Diabase at Medford, Massachusetts. By GEORGE P. MERRILL. *Bull. Geol. Soc. Am.*, 7, 349–362. — This is essentially a chemical study of the very marked decay of the coarsely crystalline and somewhat granular Medford diabase, and supplements with a more basic rock the author's investigation of the disintegrated granitic rocks of the District of Columbia. After determining the losses at 110° and on ignition, the disintegrated diabase was submitted to a mechan-

ical analysis, which yielded two grades of gravel, four of sand, two of silt and clay, the coarser grades largely predominating, and the last three (silts and clay) constituting together only 3.17 per cent. of the whole. The chemical analyses include bulk analyses of the fresh and the disintegrated diabase, and analyses for each of the portions soluble in HCl and in Na_2CO_3, and analyses of the soluble and insoluble portions of the combined silts and clay. The analyses are tabulated, and show at a glance that the disintegration is accompanied by decomposition and a leaching action, which has resulted in the removal of a portion of the more soluble constituents. Assuming the alumina to remain constant, and recalculating the analyses on a basis of 100, the net loss which the diabase has suffered is found to be 14.93 per cent., the silica showing a loss of 8.48 per cent.; iron oxides, 2.42; and lime, 1.83. The only constituent showing an increase is water. From these percentages and the bulk analysis of fresh diabase are readily obtained the actual proportions of each constituent lost and saved during the decay of the rock. This is a very instructive exhibit, the chief constituents showing the following proportional losses: K_2O, 29.15; CaO, 25.89; MgO, 21.70; Fe_2O_3 + FeO, 18.10; SiO_2, 18.03; Na_2O, 11.83.

On Malignite, a Family of Basic Plutonic Rocks Rich in Alkalies and Lime, Intrusive in the Coutchiching Schists of Poohbah Lake. By Andrew C. Lawson. *Bull. Dept. Geol. Univ. Cal.*, 1, 337–362. — After describing the geological relations and pointing out the petrographic distinctness of this new rock, which the author has named from the Canadian river (Maligne) on which it occurs, three types are distinguished as follows: *Amphibole-malignite, garnet-pyroxene-malignite, and nepheline-pyroxene-malignite.* The complete petrographic description of each type is accompanied by a chemical analysis; and the most striking fact which a review of the petrographic descriptions discloses is that intensely contrasted mineralogical, structural, and textural variations are the concomitants of very moderate changes in chemical composition. Thus the garnet-pyroxene-malignite and amphibole-malignite are very closely allied chemically, and yet the mineralogical differences are important, the first rock containing an abundance of melanite and the second none; the first having much ægerine-augite and no amphibole, and the second much soda amphibole and but little ægerine-augite.

Biological Chemistry.

S. C. Prescott, Reviewer.

The Natural Oxycelluloses. By C. F. Cross, E. J. Bevan, and C. Beadle. *J. Am. Chem. Soc.*, 18, 8–21. — This is a study of the amount and constitution of the furfurol-yielding constituents of plant tissues, selected crops of barley being used for this purpose. It was found that leaves contain a large amount of pentosans, while stems and ears contain more resistant furfuroids. The results show that the composition of the permanent tissue (cellulose) of the plant is a constant, and largely independent of conditions of cultivation. It was found that from 12 to 15 per cent. of furfurol is obtained from the entire straw in the matured state, and that the amount of cellulose extracted from the straw in paper-making yields the same amount of furfurol by boiling with condensing acids. The cereal celluloses were found to have

a composition corresponding to $3C_6H_{10}O_5.H_2O$. When prepared on a large scale the products are resolved into three groups: (1) Normal cellulose; (2) cellulose soluble in water, and forming insoluble compounds with $BaCO_3$; (3) cellulose soluble in water, but forming no Ba compounds. The chemical action of these celluloses was studied. Copper oxide is reduced after hydrolysis has been brought about. Osazones are formed by the action of phenylhydrazine on the hydrolyzed product. $KMnO_4$ in neutral solution oxidizes to acetic acid, as does also Fehling's solution. The celluloses yield acetates by treatment with acetic anhydride at its boiling point. From qualitative tests there appear to be two groups of substances — a neutral group, probably aldoses, and a more acid group, giving insoluble barium compounds. Both groups are characterized by the furfurol reactions.

A Study of Some Gas-Producing Bacteria. By A. A. Bennett and E. E. Pammel. *J. Am. Chem. Soc.*, **18**, 157–166. — A study of the gases produced by the decomposition of sugars by five kinds of bacteria was made by the authors. The gases produced were measured and analyzed by means of Hempel's apparatus. The gases produced were carbon dioxide and hydrogen, varying in amount according to the kind of sugar used. The bacteria are most active in glucose solutions in general, although cane sugar and lactose are easily fermentable by some forms. The amount of hydrogen exceeds that of carbon dioxide in all cases recorded, with one exception. This paper is very interesting from the bacteriological point of view.

Composition of Wood Gum. By S. W. Johnson. *J. Am. Chem. Soc.*, **18**, 214–223. — This paper describes the work done by chemists of the Connecticut Experiment Station upon the alkali-soluble carbohydrates of maize cobs, birch wood, and vegetable ivory. Xylan, the carbohydrate of maize cobs, is found to have a formula $C_5H_8O_4$. This is undoubtedly the anhydride of xylose, a sugar prepared by Koch from the products of hydrolysis of wood gum. This compound when separated and purified is a white, easily powdered material, almost insoluble in water, and precipitating with basic lead acetate. Xylan is not colored blue by iodine solution. As its properties correspond very closely to those of wood gum as described by Thomsen, it is probable that the formula $C_6H_{10}O_5$, which has sometimes been given to the latter, was obtained by use of moist material. The percentage composition of xylan is as follows: Carbon, 45.51 per cent.; hydrogen, 6.09 per cent.; oxygen, 48.40 per cent. — Birch wood gum has been the subject of some study, yielding preparations somewhat different from xylan. The average results are: Carbon, 47.58 per cent.; hydrogen, 6.17 per cent.; oxygen, 46.25 per cent. This corresponds nearly to a compound $C_4H_6O_3$. — Vegetable ivory yields a carbohydrate, mannan, from which mannose is obtained. This is found to have a composition $C_6H_{10}O_5$, and to be readily extracted in a very pure state by dilute caustic alkali solutions.

A Proximate Analysis of Polygala Senega. By J. H. Schroeder. *Am. Jour. Pharm.*, **68**, 178–182. — This article is of interest to pharmacists.

The Coloring Matter of the Aril of Celastrus Scandens. By Ida A. Keller. *Am. Jour. Pharm.*, **68**, 183–186. — The author finds in this plant a red coloring matter, differing in some respects from both xanthin and carotin, and possibly a connecting link between these two pigments.

E. H. RICHARDS, REVIEWER.

The Influence of Alcohol and Alcoholic Drinks upon the Chemical Processes of Digestion. BY R. H. CHITTENDEN AND LAFAYETTE B. MENDEL. *Am. J. Medical Sciences*, 111, 35–59, 163–193, 314–324, 431–450. — The authors have studied the purely chemical effects of alcohol, and of the common drinks containing alcohol, upon the rapidity of digestion of various substances, by measuring the rate of their chemical conversion. They have thus eliminated all physiological and sensory conditions, which undoubtedly have their influence in the case of the actual use of these substances. For this reason the paper has high value, since complications other than chemical have been avoided, and the conclusions so far as they go may be considered authoritative. Pure ethyl alcohol in solutions containing under 2 per cent. of absolute alcohol has little or no action upon the digestive power of the gastric juice; in some cases the digestive power on proteid foods may be slightly increased. As the per cent. of absolute alcohol rises, digestive action is reduced until with 15 to 18 per cent. it may be lessened one quarter to one third, especially with weak gastric juice. The pancreatic juice is more sensitive than gastric to the action of alcohol, 2 or 3 per cent. being sufficient to retard action. The saliva, on the other hand, is less affected, since with 5 per cent. action is sometimes accelerated, and only a slight retardation occurs with 10 per cent. It is not common, however, to take pure diluted alcohol as a drink, and the most instructive results were obtained with the different beverages. Wines as a class show far greater inhibitory effects on digestion than the stronger liquors, especially on salivary digestion, on account of their acidity. Claret is less retarding in its action on the gastric digestion than sherry. Malt liquors behave much like wines, the action being due in both cases, not to the alcohol they contain, but to the solid or extractive matters, especially acids. A most valuable practical hint may be drawn from the experiments on the effects of acids on salivary digestion. There remains to be studied the effect of alcoholic drinks upon secretion, absorption, and peristalsis, investigations in the line of physiological chemistry, before any final conclusions can be deduced.

Comparative Development of Acidity in Cream Ripened with and without "B 41." *Bull. No. 48, Univ. Wis. Agr. Exp. Station*, 1–22. — The rapidity with which acid developed was greater with the addition of the bacillus than without it when the temperatures were the same, a result the reverse of previously published results from the Storrs Station.

APPARATUS.

A. H. GILL, REVIEWER.

A Very Simple and Accurate Cathetometer. BY F. L. O. WADSWORTH. *Am. J. Sci.*, 151, 41–49. — The advantages are its convenience of manipulation, accuracy, and low cost, which is about one tenth that of the foreign instruments.

An Improved Gas Pipette for the Absorption of Illuminants. BY AUGUSTUS H. GILL. *J. Am. Chem. Soc.*, 18, 67. — To avoid the troublesome trapping of the gas by the glass beads, these are replaced by glass tubes, standing vertically, after the manner of the Orsat pipettes.

A New Balance for First Year's Work in General Chemistry. By JOHN T. STODDARD. *J. Am. Chem. Soc.*, **18**, 189. — The balance is constructed upon the principle of the Westphal balance, and is efficient and inexpensive. It is sensitive with a load of 30 grams to 0.01 gram, and with a smaller load to 0.005 gram.

A New Safety Distillation Tube for Rapid Work in Nitrogen Determinations. By CYRIL G. HOPKINS. *J. Am. Chem. Soc.*, **18**, 227. — The vapor is made to pass through side openings, the bottom being closed by the condensed liquid. The arrangement is said to prevent completely any alkali from being carried over by the distillation.

Apparatus for Testing Exit Gases. By JOHN ENEQUIST. *Am. Fertilizer*, **4**, 69. — The apparatus resembles an early form of Orsat's gas apparatus, and, with the exception of the burette, may be made from the bottles and tubing in any laboratory. Cuprous chloride, without any protection from the air, is used to absorb oxygen, the solution being kept reduced by copper gauze.

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EDITED BY ARTHUR A. NOYES.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

The Conductivity of Solutions of Acetylene in Water. BY HARRY C. JONES AND CHARLES R. ALLEN. *Am. Chem. J.*, 18, 375–377.— The molecular conductivity μ at 0° of solutions containing one molecular weight of acetylene in v liters is found by the authors to be as follows: For $v = 834$, $\mu = 29$; for $v = 1{,}666$, $\mu = 41$; for $v = 2{,}220$, $\mu = 50$; and for $v = 5{,}000$, $\mu = 77$. These values are, however, of about the same magnitude as those for acetic acid at the same dilutions and temperature, and if correct would signify that acetylene and acetic acid were acids of about the same strength, and that consequently acetylene must possess the power (which it does not have) of neutralizing bases, decomposing carbonates, and changing indicators. The authors have evidently measured the conductivity of some impurity, perhaps of ammonia coming from the decomposition of the potassium cyanide used to liberate the gas from copper acetylene. The reviewer has, in confirmation of this statement, measured the conductivity of a nearly saturated solution of acetylene prepared from calcium carbide, and found it to be practically identical with that of the pure water employed.

The Use of Phenol Phthalein in Illustrating the Dissociating Action of Water. BY HARRY C. JONES AND CHARLES R. ALLEN. *Am. Chem. J.*, 18, 377–381.— The authors point out that the fact that phenolphthalein is not reddened by ammonia in alcoholic solution (while it is reddened in aqueous solution) is a result of the much smaller degree of dissociation of the base in the former solvent, and they confirm this conclusion by comparative measurements of its electrical conductivity in pure water and in mixtures of alcohol and water. Potassium hydrate reddens the indicator in both solvents, and in correspondence therewith is found to possess a considerable conductivity even in pure alcohol. A lecture experiment based on these facts is described, serving to illustrate the effect of water in producing dissociation.

The Heat of Electrolytic Dissociation of Some Acids. BY F. L. KORTRIGHT. *Am. Chem. J.*, 18, 365–371.— The author has determined in the usual manner by electrical conductivity measurements the dissociation constants ($100k$) at 0° of twelve organic acids, and from these values, and the

constants at 25° determined by Ostwald, has calculated the heat of electrolytic dissociation Q by van't Hoff's well-known thermodynamical formula. The results are as follows:

Acid.	$100k$ at 0°.	$100k$ at 25°.	Q.
Chloracetic	0.181	0.155	— 999
Bromacetic	0.156	0.138	— 790
Malonic	0.136	0.158	+ 966
Butyric	0.00166	0.00149	— 696
Benzoic	0.00632	0.00600	— 335
o-Phthalic	0.118	0.121	+ 162
m-Phthalic	0.0202	0.0287	+ 2260
Succinic	0.00511	0.00665	+ 1697
Maleic	1.14	1.30	+ 846
Fumaric	0.0800	0.093	+ 970
Mesaconic	0.0729	0.0790	+ 518
Citraconic	0.369	0.340	— 522

The heats Q are expressed in small calories, and the negative sign indicates that heat is evolved by the dissociation. — The values for the monobasic acids are seen to be all negative, those for the dibasic acids, with one exception, all positive, the values being greater the further the two carboxyl groups are removed from each other.

On Numerical Relations Existing between the Atomic Weights of the Elements. By M. Carey Lea. *Am. J. Sci.*, 151, 386–388. — The author points out the existence of approximately constant differences of 16, 45, and 88 between the atomic weights of the elements with colorless ions in the horizontal series of his tabular arrangement (*Tech. Quart.*, 8, 307). That such differences exist in the case of almost all the elements when arranged periodically in the usual manner has long been known.

Solids and Vapors. By Wilder D. Bancroft. *Phys. Rev.*, 3, 401–417. — The article is devoted almost wholly to the discussion of the equilibrium between hydrated salts, their saturated solutions, and the vapor emitted by each. The author denies the correctness of the fundamental principle (which has been hitherto regarded as a necessary consequence of the second law of energetics) that the vapor pressure of a saturated solution and of the salt in contact with it are equal, and attempts to show that inequality of pressure does not lead to perpetual motion. The author's difficulty arises from the fact that he fails to distinguish the two kinds of perpetual motion from each other — that in which energy is continuously created from that in which the heat of the surroundings is continuously transformed into mechanical work. The first law of energetics states the impossibility of the former, and

the second law of the latter. And it is the latter kind (not the former, which the author alone considers) which would result from inequality of vapor pressure. For this inequality must obviously give rise to a continuous flow of the vapor, and it is a familiar fact that a gas in motion can be made to do work. — The author then cites experiments of Lescoeur and others to show that the vapor pressures of hydrated salts and their saturated solutions are, in fact, often very different from each other. But this, though undoubtedly true, is not a contradiction of the principle of energetics just considered; for a salt, whether hydrated or anhydrous, in contact with its saturated solution is a phase of distinct composition from the salt out of contact with its solution. The salt in the former case possesses in general a higher water-vapor pressure than in the latter, owing to the fact that it takes up or dissolves water from the solution. It is, as Roozeboom states, only at the conversion temperature that the *pure* hydrated salt and its saturated solution have the same vapor pressure; for just above (or below) that temperature the salt effloresces; that is, its own inherent vapor pressure becomes greater than that of its solution. The author, however, disputes this principle of Roozeboom. — The author further discusses the well-known effect of other dissolved substances on the conversion temperature of hydrated salts. He suggests the determination of the vapor pressure of hydrated salts by bringing them into contact with the vapor of aqueous sulphuric acid solutions of varying concentration and noting the point at which efflorescence begins to take place, but draws the improbable conclusion that their vapor pressure is essentially affected by the minute quantity of sulphuric acid which evaporates from the solutions.

On the Color Relations of Atoms, Ions, and Molecules. II. By M. Carey Lea. *Am. J. Sci.*, 151, 405–416. — The author illustrates by a large number of examples the well-known fact that ions and the molecules resulting from their union are often differently colored. He denies the correctness of the explanation of indicators given by the dissociation theory, which regards them as very slightly dissociated acids (or bases) whose salts are largely dissociated into ions having a color different from that of the undissociated acid (or base). His objections to this explanation are that the indicators do not show a change of color on dilution alone, as they should on account of the increasing dissociation, and that their dry undissociated salts are of the same color as their solutions. The first objection rests on a misconception of the quantitative relations; for the dilution at which an appreciable dissociation takes place is so great in the case of such weak acids that the color of the indicator has entirely disappeared. The second objection, even if the fact stated were generally correct, which it is not, is plainly irrelevant. — The author further discusses his color classification of the elements previously reviewed (*Tech. Quart.*, 8, 307) and the rather indefinite question whether ions are "free."

On the Densities of Oxygen and Hydrogen, and on the Ratio of Their Atomic Weights. By Edward W. Morley. *Smithsonian Contributions to Knowledge*, 980, 1–117. — This valuable monograph describes in great detail the apparatus and methods employed and the results obtained by the author in his incomparable investigations on these subjects. The results have been already given (*Tech. Quart.*, 8, 305). The paper is accompanied by forty illustrations, and is divided into four parts, treating respectively of the Density of Oxygen, the Density of Hydrogen, the Volumetric Composition of Water, and the Synthesis of Water from Weighed Quantities of Hydrogen and Oxygen.

H. M. GOODWIN, REVIEWER.

The Conductivity of Yttrium Sulphate. BY HARRY C. JONES AND CHARLES R. ALLEN. *Am. Chem. J.*, 18, 321–322. — The following values were obtained for the equivalent conductivity of aqueous solutions of yttrium sulphate, very carefully prepared from material used by Mr. Jones in his determination of the atomic weight of yttrium. v denotes the number of liters containing one-sixth gram-molecular weight of yttrium sulphate:

v.	μ_v.	v.	μ_v.
6.49	23.2	.....	.....
12.98	27.8	1,661	102.6
25.96	32.5	3,323	123.8
51.92	38.5	6,646	152.6
103.8	36.9	13,290	192.9
207.7	54.0	26,580	240.7
415.4	66.6	53,170	333.3
830.7	78.8	106,330	601.1

On the Heat Effect of Mixing Liquids. BY C. E. LINEBARGER. *Phys. Rev.*, 3, 418–431. — "Normal" liquids were chosen for these experiments, as the relations holding were more likely to be simple than with liquids whose molecules are "associated." The heat developed or absorbed on mixing such liquids was measured in an ice calorimeter. The results show that it is not possible to predict whether an absorption or evolution of heat will occur. Thus both ethyl ether and ethyl iodide mix with toluene without an appreciable thermal change, while on mixing with each other considerable heat is developed. Another anomaly was observed in the case of carbon tetrachloride, chloroform, and toluene. The first and second of these substances, and also the second and third, when mixed together gave a heat absorption, while mixtures of the first and third gave an absorption or development of heat according to the proportions. The author concludes from experiments of Schüller, Alexejew, and Perrot that temperature has no influence on the thermal effect of mixing normal liquids.

A Rapid Method of Determining the Molecular Masses of Liquids by Means of Their Surface Tensions. BY C. E. LINEBARGER. *J. Am. Chem. Soc.*, 18, 514–532. — In the method described two vertical parallel capillary tubes of different bore are used, one being fixed, the other movable in a vertical direction by means of a micrometer screw reading to $\frac{1}{4000}$ inch. The two tubes are connected by rubber tubing and a glass Y tube to a common air reservoir (a rubber ball), the pressure in which may be increased at will by means of a screw. The capillaries dip in the liquid whose surface tension is desired. This is contained in a test-tube properly jacketed by various baths for maintaining constant temperatures. The pro-

cedure consists in first adjusting accurately the capillaries so that their ends lie in the same plane. Air under slight pressure is then forced through the larger capillary, and the distance h, which the other tube must be raised in order that bubbles of air shall just issue through both tubes simultaneously, is then measured by means of the micrometer. The temperature and specific gravity s of the liquid must also be noted. The author finds the empirical equation $\gamma = chs + s^2$ best represents the relation between the surface tension γ and the quantities measured above, c being the apparatus constant, which is determined by substituting for γ data from Ramsey and Shield's papers on surface tensions of liquids. The values of c calculated from data on ten different liquids at different temperatures agree in general within a few tenths of a per cent. The author points out, however, that this degree of accuracy in the absolute values of the surface tension is not to be expected, as the apparatus constant may change from liquid to liquid by a much greater amount. Jäger's formulæ were found to lead to only roughly approximate results. The applicability of the method to the determination of the molecular mass of benzene and acetone is illustrated by actual measurements.

Inorganic Chemistry.

H. Fay, Reviewer.

A Review of Some Recent Work on Double Halides. By Charles H. Herty. *Am. Chem. J.*, 18, 290–294. — This paper contains a criticism of the methods employed in this particular field of research, and a plea for more care in the preparation of pure compounds, and greater accuracy in analytical work. The author calls attention particularly to work done on the double halides of lead and the alkalies. A large number of compounds have been described, but after repetition of the work the large number is gradually diminishing. Five double halides of lead and potassium have been described, but by working with greater care and using improved methods of analysis this number has been decreased to one, the compound $KPbI_3.2H_2O$. In spite of the accuracy with which this work was done by the author, under the direction of Professor Remsen, and its confirmation by Wells and by Schreinmakers, other papers appeared describing new salts. Mosnier, in a preliminary paper upon compounds of lead iodide and metallic iodides, describes the salts $3PbI_2.4KI$ and $3PbI_2.4NH_4I$. Miss E. Field, working separately, described the same compounds. It had already been shown that the first of these salts could not exist, and the author repeats the work, using the iodides of lead and ammonium and following Miss Field's directions for the preparation of the salt. Crystals were obtained which under the microscope seemed perfectly pure. The analysis gave results corresponding to the formula $NH_4PbI_3.2H_2O$, which is entirely analogous to the potassium salt. The analysis published by Miss Field gives a total of 96.79 per cent., and from this she derived her formula. In the same paper she also described a double salt of the formula $PbI_2.3PbCl_2$. The author repeated the work, following very closely the directions given. The analytical results show plainly that the substance described is an isomorphous mixture of lead iodide and lead chloride.

Silicide of Calcium. By G. de Chalmot. *Am. Chem. J.*, 18, 319–321. — In previous work on silicides the author, in using lime as a flux to make the mixture more liquid, noticed that the resulting silicide contained considerable amounts of calcium. In this way calcium has been introduced into the

silicides of copper, silver, iron, and manganese. By heating together carbon, lime, and sand in an electric furnace in proper proportions to form the compound $CaSi_2$, mainly carbide of calcium is formed, but if silica be used in excess and the amount of carbon reduced, a calcium silicide of metallic appearance can be obtained, especially if a direct current of low voltage (25 volts and 225 amperes) be used. The analytical data show the compound to have more silicon and less calcium than required by the formula $CaSi_2$. The reactions which Wöhler described for calcium silicide ($CaSi_2$) were obtained with all these specimens.

The Occurrence of Titanium. By CHARLES E. WAIT. *J. Am. Chem. Soc.*, 18, 402–404. — The author calls attention to the fact that in a recent examination of food materials, under the direction of the United States Department of Agriculture, he has found titanium present in the ash of every plant examined. In the ash of oak wood he finds 0.31; in apple and pear wood mixed, 0.21; in apple, 0.11; in cow peas, 0.01; in cottonseed meal, 0.02 per cent. The examination of the ash of bituminous coal gave results on different samples varying from 0.69 to 0.83 per cent., while Pennsylvania anthracite gave 2.59 per cent. titanium. The method of analysis employed was that of Weller, depending upon the depth of color obtained on bringing together solutions of titanium and hydrogen peroxide.

On the Formation of Antimony Cinnabar. By J. H. LONG. *J. Am. Chem. Soc.*, 18, 342–347. — The formula for antimony cinnabar, made by boiling a solution of antimony chloride or tartrate, with sodium thiosulphate, has been established as Sb_2S_3, and, according to the author's work published in a previous paper, antimony trioxide and thiosulphuric acid are first formed, these substances reacting to form the sulphide, the sulphur dioxide and oxygen produced being held as polythionate. To throw further light on the reaction attempts were made to form the cinnabar by other methods. While the product is always Sb_2S_3, the characteristic color can only be obtained by the decomposition of a thiosulphate in a neutral or acid solution. Dilute or concentrated solutions of pure antimony trioxide and sodium thiosulphate, if neutral, do not react even under pressure of eighteen atmospheres. It was found, however, that the addition of acid causes the reaction to take place slowly. The amount of sulphide formed is not proportional to the volume of acid added. The reaction seems to take place between antimony trioxide and thiosulphuric acid, as suggested by experiment. Neutral sodium thiosulphate added to antimony trioxide in hydrochloric acid showed no precipitation until after some time, but acidified sodium thiosulphate added to antimony trioxide produced a precipitate of Sb_2S_3 almost immediately. When hydrochloric acid is added in sufficient quantity to set free all of the thiosulphuric acid, less than one third of the antimony trioxide is changed to sulphide. This the author shows to be due to the liberation of sulphur dioxide, which probably protects the sodium thiosulphate. Sulphurous acid added to the solution almost entirely prevents the formation of antimony cinnabar. The cinnabar is most easily formed from the oxychloride of antimony, the hydrochloric acid formed setting free the thiosulphuric acid, which immediately enters into the reaction.

A Study of the Zirconates. By F. P. VENABLE AND THOMAS CLARK. *J. Am. Chem. Soc.*, 18, 434–444. — The various methods proposed by Ouvrard, Ebelman, and Hiartdahl for the formation of zirconates are reviewed and studied by the authors. The method of Ebelman of fusing zirconia with

boron trioxide was not successful in forming zirconates, as the zirconia was not dissolved after long continued heating. The zirconia used was dried at the temperature of the steam bath, so that it was not in the inactive condition. Fusing with alkaline carbonates was scarcely more successful. Very little action took place, and the time of heating did not affect the results. After cooling, the fused mass was leached with successive portions of water until no more alkali could be detected. Dilute hydrochloric acid was used to separate the mass from unattacked zirconia. With sodium carbonate two results obtained agree only fairly well with the formula $(Na_2O)_2(ZrO_2)_3$. Separate fusions carried out under the same conditions do not give the same result. With potassium carbonate there was no noticeable action. Sodium and potassium hydroxides gave good fusions, but the products vary in composition from $(Na_2O)(ZrO)_6$ to $(Na_2O)(ZrO)_8$, and from $(K_2O)(ZrO_2)_3$ to $(K_2O)(ZrO_2)_5$. Lithium gave no zirconate when the carbonate was used, but with the hydroxide it gave a product corresponding to the formula $Li_2O.2ZrO_2$. The oxides of calcium, barium, strontium, and magnesium gave products agreeing with the general formula M_2ZrO_3. Experiments showed that there was no action between zirconia and the different alkali and alkaline-earth chlorides. Precipitation of a zirconium salt by an alkaline hydroxide gave no definite product, the alkali found in the precipitate being mechanically inclosed. The tendency to form polyzirconates the authors think may be due to the decomposing action of water. Calcium zirconate was prepared containing a small percentage of potassium, and a zirconate containing aluminum and potassium.

Hydrofluoric Acid. By KARL F. STAHL. *J. Am. Chem. Soc.*, **18**, 415–425. — Already abstracted from another journal (*this Rev.*, **2**, 8).

H. P. TALBOT, REVIEWER.

On the Reaction between Carbon Tetrachloride and the Oxides of Niobium and Tantalum. By M. DELAFONTAINE AND C. E. LINEBARGER. *J. Am. Chem. Soc.*, **18**, 532–536. — The products resulting from the action of carbon tetrachloride upon niobic acid at 400°C. are oxychloride of niobium and niobium pentachloride, the former in larger amounts. The acid was heated to the required temperature in a current of carbon dioxide. The two products distill and condense in the cooler portion of the tube, and from the mixture, by careful manipulation, the pentachloride may be isolated by the application of heat. The absolute exclusion of oxygen and the introduction of chlorine failed to increase the yield of the chloride. This is a fresh illustration of the tendency of niobium to form niobyl compounds, as in the case of the oxychloride $2NbO.Cl_3$. Tantalic acid gave no sublimable product even at high temperatures, except a small amount of what appeared to be a niobyl compound, due to contamination. The tantalic oxide became yellow and pasty.

The Reduction of Copper Sulphide. By DELIA STICKNEY. *Am. Chem. J.*, **18**, 502–504. — The author notes that copper sulphide, prepared by heating together copper and sulphur, may be reduced by contact with the flame of a Bunsen burner. During the reduction the mass shows a change to blue, green, and shades of red, and under the lens shows many threads of metallic copper. The reduced portion of the mass is soft and friable, and seems to consist of copper and some unchanged copper sulphide. The higher temperature of the blast lamp does not promote the reaction. The addition of a little sulphur may shorten the time required for reduction.

Organic Chemistry.

J. F. Norris, Reviewer.

Perhalides of Caffeine. By M. Gomberg. *J. Am. Chem. Soc.*, 18, 347–377. — The author offers a classification of organic perhalides to which all yet described can be referred, and describes a large number of perhalides of caffeine, bromocaffeine, and chlorocaffeine. By avoiding the presence of hydriodic acid, periodides were obtained containing hydrochloric and hydrobromic acids. The general method of procedure was to treat a solution of the alkaloid and iodine in chloroform with the dry halogen acid. In this way compounds of the structure Alk.HX.Y, where X is Cl, Br, or I, and Y is I_3, I_4, and I_5, were obtained. Perbromides of the hydrobromides and hydrochlorides containing two, four, and five "exterior" bromine atoms are also described. The work justifies in a certain degree the following conclusions: (1) Organic bases are capable of forming periodides not only of their hydriodide salts, but also of their hydrobromides and of their hydrochlorides. (2) When a base forms periodides it is capable of forming perbromides. (3) The number of iodine atoms which a base takes up is not an index of its basic power.

The Cis and Trans Modifications of Benzene Hexabromide. By W. R. Orndorff and W. A. Howells. *Am. Chem. J.*, 18, 312–319. — Benzene hexabromide was made as follows: 650 grams bromine were added (50 grams daily) to 100 grams benzene floating on 300 cc. of a 1 per cent. solution of sodium hydroxide. After the addition of all of the bromine the resulting oil was allowed to stand in an open flask for eight weeks. The crude benzene hexabromide thus formed, after repeated treatment with alcohol to remove substitution products, was separated into two portions by extracting with chloroform. The crystals from the chloroform, recrystallized from benzene, melted at 212°–213°, had a molecular weight corresponding to $C_6H_6Br_6$, and proved to be the hexabromide already described (α). The insoluble portion (about 0.6 gram) melted at 253°, and on analysis proved to be an isomer (β). The measurements of the crystals of the α-hexabromide agree in general with those already given. The β-hexabromide crystallizes in the regular system, whereas the corresponding hexachloride is hexagonal. It is probable that the α-variety is the trans compound from the larger amount formed, the system in which it crystallizes, the lower melting point, and the complete analogy of the substance with the trans hexachloride. The smaller amount of the β-compound formed, its crystal line form, and its higher melting point indicate that it is the cis stereomer.

The Preparation of Allylene and the Action of Magnesium on Organic Compounds. By Edward H. Keiser. *Am. Chem. J.*, 18, 328–333. — The method recently proposed by Keiser and Breed (*Tech. Quart.*, 8, 426) for the preparation of allylene has been improved by substituting acetone for allyl alcohol. The vapor of acetone is passed over glowing magnesium powder and the resulting black mass decomposed with water containing a little ammonium chloride. Methyl, ethyl, propyl, isopropyl, allyl, isobutyl, and amyl alcohols reacted in the same way. The gas evolved in each case was shown to be allylene by analyses of its silver and copper compounds. From the small amount of oxides of carbon in the gases produced while the

magnesium was glowing in the vapor of the alcohols it is probable that the metal combines with the oxygen of the alcohols; hydrogen and hydrocarbons are thereby formed, and a portion of the magnesium unites with these compounds, forming magnesium allylide. The yield of the latter is 10 per cent. when acetone is used, if it is assumed that the reaction is $2C_3H_6O + 3Mg = 2MgO + Mg(C_3H_3)_2 + 6H$.

The Action of Urea and Sulphocarbanilide on Certain Acid Anhydrides. By FREDERICK L. DUNLAP. *Am. Chem. J.*, 18, 332–341.— Phthalimide was prepared by heating equal molecules of phthalic anhydride and urea at 150° until the melted mass solidified. A 90 per cent. yield of the pure product was obtained. The reaction takes place in two stages:

$$C_6H_4\begin{cases}CO\\CO\end{cases}O + NH_2CONH_2 = C_6H_4\begin{cases}CONHCONH_2\\COOH\end{cases},$$

$$C_6H_4\begin{cases}CONHCONH_2\\COOH\end{cases} = C_6H_4\begin{cases}CO\\CO\end{cases}NH + CO_2 + NH_3.$$

Urea reacts with dichlor- and dibrommaleïc anhydride in an analogous manner. If the two substances are heated for a few minutes at a temperature about 10°–15° above the melting point of the mixture, the first stage of the reaction alone is completed. In this way 50 per cent. yields of dichlormaleïnuric acid melting at 158° and dibrommaleïnuric acid melting at 191° were obtained. If the mixture of urea and the acid anhydride is heated for a short time at 25°–30° above its melting point 24 per cent. of the imide is formed. It was impossible to stop the reaction between urea and succinic anhydride at the first stage. Above 280° succinimide was obtained as a distillate. The yield was 40 per cent. Succinuric acid prepared according to the method of Pike melted at 211°–211.5°, and not at 203°–205°, as stated, and furnished a distillate of succinimide when heated above 280°. When phthalic anhydride is heated at 125°–130° with sulphocarbanilide, addition takes place as with urea, but the resulting compound breaks down immediately:

$$C_6H_4\begin{cases}CONC_6H_5CSNHC_6H_5\\COOH\end{cases} = C_6H_4\begin{cases}CONHC_6H_5\\COOH\end{cases} + SCNC_6H_5.$$

A 60 per cent. yield of phthalanilic acid melting at 169°–169.5°, and not at 192°, as stated by others, was thus obtained. If the reaction is effected at 170°–175°, phthalanil, $C_6H_4\begin{cases}CO\\CO\end{cases}NC_6H_5$, is formed. A 90 per cent. yield of succinanil was obtained, when succinic anhydride was heated at 150°–155° with sulphocarbanilide.

The Action of Light on Some Organic Acids in the Presence of Uranium Salts. By HENRY FAY. *Am. Chem. J.*, 18, 269–290.— The author has found that oxalic acid in the presence of uranyl oxalate decomposes under the influence of sunlight into carbon dioxide, carbon monoxide, and formic acid. The volume of carbon monoxide found was approximately half of the carbon dioxide found, the other half being used in the formation of the formic acid. If the excess of oxalic acid is large and the reaction is incomplete, crystals of $U(C_2O_4)_2.6H_2O$ are deposited; but, if the reaction is completed, part of the uranium present is precipitated as uranous oxalate,

and the rest, which is probably present as uranyl oxalate, is precipitated as a purplish brown powder. This latter precipitate is also formed when uranyl oxalate alone is exposed to the direct sunlight. On standing some time it changed into a yellow substance which contains 75 per cent. uranium, 1.20 per cent. carbon, and 8.50 per cent. water. It was found further that acetic, propionic, and isobutyric acids, when exposed with uranyl nitrate, are decomposed into carbon dioxide and the corresponding hydrocarbon, these two gases being given off in equal volumes. An attempt was made to study the rate of decomposition, but there was usually formed after several days' exposure a precipitate of a uranous compound, which hindered the reaction. With tartaric acid there was no evolution of gas, but all of the uranium was precipitated as a uranous compound, the nature of which has not been determined.

On the Existence of Two Orthophthalic Acids. By W. T. H. Howe. *Am. Chem. J.*, 18, 390–401. — An effort to determine the true melting point of orthophthalic acid has led to the discovery of two acids identical in composition, molecular weight, and molecular refraction, but differing in melting points, electrical conductivity, solubility, the properties of their salts with organic and inorganic bases, and in their reduction products. The *a*-acid melts at 203° and the *β*-acid at 184°. The latter is converted into the *a*-variety by boiling with water, while the reverse change takes place by the action of strong acids or alkalies. The isomerism is best explained by using Kekulé's benzene formula. In one case the carboxyl groups are separated by a double bond, in the other by a single bond. This explanation is plausible from the behavior of the *β*-acid on reduction as compared with the *a*-acid as studied by Baeyer. The *β*-acid yields a new dihydrophthalic acid which is more unstable than the $\Delta^{3,5}$ body obtained by Baeyer from the *a*-acid. It differs from that compound by reducing a cold silver nitrate solution and by being reduced by sodium amalgam at a low temperature to two tetrahydroorthophthalic acids. Upon the basis of Baeyer's work the new dihydro acid seems to be the $\Delta^{1,3}$ compound. Of the two tetrahydro acids, one agrees in its melting point and that of its anhydride, as well as in its solubility, with the Δ^{1} compound of Baeyer. The other is a new acid, and since only the cis and trans Δ^{3} compounds are lacking it must be one of these. If this is the case, the double bond is between the carboxyl groups in *β*-orthophthalic acid. Commercial phthalic acid is a mixture of the two acids, but, if an aqueous solution of it is boiled for four hours, the *a*-acid is obtained in pure condition. To prepare the *β*-acid, the anhydride is dissolved in dilute sodium hydroxide, the solution cooled to 0°, and the acid slowly precipitated with hydrochloric acid. Phthalic anhydride appears to be the anhydride of the *β*-acid. When a concentrated alkaline solution of the *β*-acid is acidified, a mixture of the acid with an acid salt is precipitated. Affinity-constants: *a*-acid, 100K = 0.121; *β*-acid, 100K = 0.137. Solubility in 100 parts of alcohol at 20°: *a*-acid, 11.74 parts; *β* acid, 14.12 parts. The salts of the two acids with aniline, naphthylamine, quinoline, and brucine differ in crystal form and melting point. The new dihydro acid prepared by Baeyer's method from the *β*-acid melts at 195°, and gives an anhydride melting at 126°. The new tetrahydro acid melts at 206°, its anhydride at 112°–113°. The metallic salts of the two phthalic acids differ in form and in water of crystallization, the *β*-salt being always the more unstable.

The Action of Acid Chlorides on the Silver Salts of the Anilides. By H. L. Wheeler and B. B. Boltwood. *Am. Chem. J.*, 18, 381–390. — In this paper the authors describe the action of benzoyl chloride on the silver salts of formanilide, 2–4 dichlorformanilide, and formtoluide. The resulting products were found to be diacid anilides and a diacid toluide of the general formula $R - N\begin{smallmatrix}CHO\\COC_6H_5\end{smallmatrix}$. By the decomposition of these new bodies with acids and alkalies the formyl group is replaced by hydrogen. From this it is assumed that a direct double decomposition takes place, and that in the silver salt of the anilide the metal is joined to nitrogen. On the other hand, if the diacid anilides were oxygen derivatives of the general formula $R - N = C\begin{smallmatrix}H\\O - COC_6H_5,\end{smallmatrix}$ it would be difficult to explain the removal of the formyl group. The authors' conclusion is opposed to that of Comstock and others, who have shown that with alkyl halides the silver salts of the anilides give imido ethers. The experimental evidence leads to the belief that the silver salts of the anilides may exist in two forms, and that an addition first takes place with subsequent separation of silver chloride. That the structure of the silver salts of the anilides cannot be decided by their final reaction products is shown by the above considerations. The authors show in the same paper that, when chlorcarbonic ethyl ester and silver formanilide react, both the oxygen derivative, phenylformido ethyl ether, and the nitrogen compound, formylphenylurethane, are formed. The reaction with formorthotoluide appears to be similar.

On the Existence of Pentaethyl Nitrogen. By Arthur Lochman. *Am. Chem. J.*, 18, 372–375. — Two unsuccessful attempts to prepare pentaethyl nitrogen, $(C_2H_5)_5N$, are described. A mixture of tetraethylammonium iodide and zinc ethyl, diluted with ether, after standing six weeks, when poured into water showed a strong alkaline reaction and slowly deposited a red crystalline precipitate. This, from its properties and analysis, seems to be tetraethylammonium triiodide, $(C_2H_5)_4NI_3$. Triethylamine dibromide, $(C_2H_5)_3NBr_2$, when treated with zinc ethyl reacted like a mixture of triethylamine and bromine. No synthesis was accomplished. With phenyl-iodide dichloride, zinc ethyl gave phenyl iodide, ethyl chloride, zinc chloride, and zinc oxychloride.

Analytical Chemistry.

Ultimate Analysis.

H. P. Talbot, Reviewer.

Särnström's Method of Determining Manganese in Iron Ores. By C. T. Mixer and H. W. DuBois. *J. Am. Chem. Soc.*, 18, 385–389. — About 0.5 gram of the ore is brought into solution in 10–15 cc. of hydrochloric acid, supplemented by a fusion of the residue if required, and the iron is oxidized by nitric acid, with subsequent boiling to remove nitrous compounds. The solution should contain a reasonable excess of free hydrochloric acid, and sodium carbonate be added in but slight excess over the amount required to throw out the iron. Särnström originally employed the bicarbonate at this point, but the authors do not find this advantageous. The solution is diluted with boiling, distilled water until a "No. 3 beaker" is two-thirds full, when it

is at once titrated with standard potassium permanganate solution to an end-point which is permanent after gentle heating and vigorous stirring. As in the Volhard process, two molecules of the potassium permanganate react with three molecules of the manganous oxide. With ores very low in iron it is advisable to add ferric chloride, as the presence of the iron promotes the titration. The process was not found to be successful for ores high in manganese, nor for ferromanganese, as it yields low results. The authors do not recommend the method for use with irons and steels on account of the difficulty in handling large quantities of iron. The procedure as presented is found to yield results which are accurate within 0.2 per cent. for ores as high as 15 per cent., and within a few hundredths of a per cent. for ores under 1 per cent. Särnström's original paper was published in the *Jernkontorets Annaler*, 1881, 401.

On the Various Modifications of the Pemberton Volumetric Method for Determining Phosphoric Acid in Commercial Fertilizers. By F. P. Veitch. *J. Am. Chem. Soc.*, 18, 389–396. — The paper deals chiefly with the question as to whether the adherence to exact conditions regarding time and temperature during precipitation cannot be dispensed with, and discusses the question with regard to the method of filtering and washing, and the time of standing after adding the molybdate solution, both with and without the introduction of tartaric acid to prevent the deposition of molybdic acid. It was found that the use of pressure during filtration offered no advantage when a large number of determinations were carried on simultaneously, and that water best serves to wash the precipitate. The washing is complete when the wash water is neutral to litmus. It was found further that with the official molybdate solution, to which 10 cc. of nitric acid (1.42 sp. gr.) have been added, and an interval of one half hour at 40°–50° C., results were obtained comparable with the gravimetric methods. The use of tartaric acid with this modified molybdate solution (1 gram of the acid per 100 cc.) gives satisfactory results, but it possesses no advantage over the other procedure, and the time of standing must be increased. The best results were obtained by allowing the solution to stand over night in the cold. The paper contains tables of results of analyses from which these conclusions are drawn.

The Estimation of Pyrrhotite in Pyrites Ores. By Edwin F. Cone. *J. Am. Chem. Soc.*, 18, 404–406. — The ore is ground until it passes a 60-mesh sieve (but should not be finer than this), and a weighed quantity (13.74 grams) spread out upon a glazed paper. A magnet is passed through and over this several times, the magnetic portion being detached by suddenly stroking the magnet on the top, to remove the pyrite mechanically held, and subsequently brushing off the magnetic pyrrhotite. By repeating this procedure five or six times a practically complete separation is effected. The sulphur is then determined in the magnetic portion, and if the above weight be taken, the weight of barium sulphate in grams is the percentage of sulphur present as pyrrhotite. The author claims that the method is accurate to 0.2 per cent. on ores containing much or little pyrrhotite.

Drown's Method of Determining Sulphur in Pig Iron. By George Auchy. *J. Am. Chem. Soc.*, 18, 406–411. — The author recommends two modifications of the original procedure, namely, the use of an alkaline solution of potassium permanganate as an absorbent, and the use of oxalic acid with the hydrochloric acid, to destroy the excess of permanganate before the precipitation of the barium sulphate. It is claimed that the rate of evolu-

tion of the gas may be so increased that it is complete in five minutes, since its passage through the absorption bulbs may be safely hastened if the alkaline permanganate be used. The use of oxalic acid with the hydrochloric acid lessens the tendency toward separation of silicic acid, and promotes the reduction. It appears from the results of the experiments cited that an excess of oxalic acid in no way interferes with the precipitation of the barium sulphate, and that the solvent effect of hydrochloric acid upon the barium sulphate is materially increased by the presence of ammonium chloride. When ammonium salts are present the free acid should be nearly neutralized before precipitation. — In connection with a later article (p. 498) the author mentions, as an additional precaution, that the solution from the absorption tubes should be boiled, with addition of a little permanganate, to insure complete oxidation of any sodium sulphide which might form. It is not easy to see how the formation of sulphide can occur if, as the author states, potassium manganate be a better oxidizing agent than the permanganate.

A Modified Ammonium Molybdate Solution. By A. L. Winton. *J. Am. Chem. Soc.*, 18, 445–446. — To avoid the addition of ammonium nitrate to solutions of phosphoric acid from fertilizers, before the addition of ammonium molybdate solution, it is proposed to prepare the latter solution in such a way that 50 cc. shall contain the requisite quantity of ammonium nitrate. To do this, dissolve 1,000 grams of molybdic acid in 4,160 cc. of a mixture of one part ammonia water (0.90 sp. gr.) and two parts water. Dissolve also 5,300 grams of ammonium nitrate in a mixture of 6,250 cc. of concentrated nitric acid (1.4 sp. gr.) and 3,090 cc. of water. Mix the two solutions slowly, with constant stirring, and allow the mixture to stand a few days in a warm place. Decant the clear liquid. If more than 50 cc. be required, the additional quantity of ammonium nitrate introduced is not harmful.

On the Estimation of Sulphur in Pyrites. By Thomas S. Gladding. *J. Am. Chem. Soc.*, 18, 446–449. — This paper continues a discussion between the author and Professor Lunge regarding the details of the sulphur determination. The author furnishes experimental data in support of his statement that the rapid addition of the barium chloride solution occasions contamination of the barium sulphate by barium chloride, and that this source of error is not offset by the solubility of the sulphate in the acid liquor from which precipitation takes place. (Compare *Tech. Quart.*, 8, 184, 187, 404.)

A Simple Method for Determining the Neutrality of the Ammonium Citrate Solution Used in the Analysis of Fertilizers. By N. W. Lord. *J. Am. Chem. Soc.*, 18, 457–458. — Pure litmus solution is added to about 200 cc. of distilled water until distinctly colored, and of this 100 cc. are diluted with an equal volume of water. Two 50 cc. Nessler tubes are filled with the diluted solution, and one with the stronger solution. To one of the former tubes a drop of dilute sulphuric acid is added, to the other a drop of ammonia water. By super-imposing these tubes a perfectly neutral tint is obtained. To the liquid in the third tube 5 cc. of the citrate solution are added and the color compared with the neutral tint. From the amount of acid or alkali required to produce this tint with the 5 cc. of the citrate solution the total required for the entire volume is calculated. The results are said to be very satisfactory and comparable with Huston's method with alcoholic solutions of calcium chloride, which it surpasses in ease of execution.

The Copper Assay by the Iodide Method. By ALBERT H. LOW. *J. Am. Chem. Soc.*, **18**, 458–462. — The procedure, which is also described in Peter's *Modern Copper Smelting*, is essentially the following: The ore is treated with nitric acid, taken to dryness, and redissolved in hydrochloric acid, which is subsequently replaced by sulphuric acid. Insoluble sulphates are filtered off, and the copper is precipitated by the introduction of aluminum foil. This copper is dissolved in nitric acid in slight excess, with the addition of a little potassium chlorate; zinc acetate is added in sufficient quantity (6–7 grams) to combine with the excess of acid, and potassium iodide is added, from which the cupric compounds liberate iodine. This iodine is titrated with sodium thiosulphate. The author lays special stress upon the following points: The nitric acid solution of the copper must be thoroughly boiled to remove nitrous compounds, and the addition of the potassium chlorate is necessary to oxidize arsenic to arsenic acid. He points out that with small quantities of copper the liberation of the iodine is more quickly accomplished in the presence of an excess of the potassium iodide, and recommends the addition of 3 grams, no matter if the quantity of copper be small since an excess is not harmful. Silver does not interfere, nor do lead and bismuth except by the formation of yellow iodides, which may obscure the end-point. The presence of either free nitric acid or nitrous compounds will cause uncertainty as to the end-point of the titration. Sodium acetate cannot be substituted for zinc acetate. If it be known that nearly all the nitric acid has been expelled, half the prescribed quantity may be safely used.

A Method for Separating "Insoluble" Phosphoric Acid in Mixed Fertilizers Derived from Bone and Other Organic Matter from that Derived from Rock Phosphate. By A. P. BRYANT. *J. Am. Chem. Soc.*, **18**, 491–498. — The separation of the bone or other organic matter from the rock phosphates is accomplished through differences in specific gravity. The fertilizer is first treated with from 100 to 250 cc. of water in an extraction apparatus made by closing the end of a tube with filter paper, reinforced by cheese-cloth, to remove the water-soluble phosphoric acid. The residue is dried and carefully separated. It is then shaken with a solution of mercuric iodide of specific gravity exactly 2.26, which allows the rock phosphates to sink, but supports the organic matter on its surface. The separation takes place in a long, narrow tube divided into two sections by a piece of rubber tubing. This is closed by a pinch-cock, and the heavier portion of the fertilizer in the lower section and the lighter portion in the upper section are filtered off, washed, dried, and subjected to analysis. The separation appears to be quantitative.

Sources of Error in Volhard's and Similar Methods of Determining Manganese in Steel. By GEORGE AUCHY. *J. Am. Chem. Soc.*, **18**, 498–511. — The author has made a critical study of the Volhard method and Stone's modification. (Compare *this Rev.*, **2**, 16.) He finds that the destruction of the organic matter present in the steels is not essential, but that considerable care is necessary in effecting the precipitation of the iron by zinc oxide. If the latter be added only in sufficient quantity to coagulate the iron, the apparent percentage of manganese found is too high, while a large excess of zinc oxide suddenly added causes results below the true percentage. The best results are obtained if the zinc oxide be carefully added to coagulation, to avoid dragging down manganese, and then a reasonable excess be subse-

quently added to insure complete neutralization. Even then, if Stone's modification, which seems on the whole the best, be used, a correction of 0.02 per cent. must be deducted from the percentage found. (It seems to the reviewer that, while this correction may be proper for steels containing about 0.40 per cent. manganese, it is doubtful what the same correction should be when applied to steels decidedly richer or poorer than this grade.) In any case the neutralization should take place in the cold, and correction must be made for any action of either the sal soda, or zinc oxide upon permanganate. The author does not consider the addition of zinc, lime, magnesia, etc., as proposed by Volhard, to be essential. — In connection with the color method for manganese, it is suggested that it is well to take a series of observations and average them, rather than to trust to a single reading.

Gravimetric Determination of Selenium. By A. W. Peirce. *Am. J. Sci.*, 151, 416–418. — The reduction of selenious acid to selenium takes place more rapidly under treatment with potassium iodide in acid solution, than with sulphurous acid. The selenious acid is brought into solution, diluted to 400 cc., acidified with hydrochloric acid, and potassium iodide added to an amount about 3 grams in excess of the quantity theoretically required to react with the selenious acid. The solution is then boiled from ten to twenty minutes, during which the selenium is converted into the black modification, and the iodine is largely removed. The selenium is collected on an asbestos felt, washed, and dried at 100° C. The precipitation and washing may be accomplished in half an hour. It is essential that an excess of potassium iodide be employed in order to extract all liberated iodine from the precipitated selenium, and, on the other hand, the solution must be freely diluted to avoid inclosure of potassium iodide. There is a slight positive error, but the results furnished are satisfactory. Selenic acid may also be reduced by the same procedure and the selenium weighed.

Notes on the Analytical Determination of Silica. By Ferdinand G. Wiechmann. *School Mines Quart.*, 17, 220–225. — The author points out that in order to secure complete dehydration of silicic acid by heat the first filtrate from the silica must be again evaporated and subjected to the dehydrating temperature. The fact that this matter has been fully treated by Gilbert (*Tech. Quart.*, 3, 61) appears to have been overlooked. It is difficult to understand why the silicic acid should be heated for such unnecessarily protracted periods as sixty-four or even sixteen hours at 101° C., if it is to be subsequently heated over the direct flame of a Bunsen burner. The quotation from Ostwald's *Scientific Foundations of Analytical Chemistry* as regards the necessity for the use of temperatures above the boiling point of the liquid employed for washing, when drying precipitates, appears to the reviewer to be irrelevant as applied to the dehydration of the silicic anhydride, which involves the removal of water of constitution and not merely the drying of the silica. — The results are given of a series of experiments intended to show the action of potassium hydrate, sodium hydrate, and sodium carbonate upon crystalline silica, and upon mixtures of crystalline and amorphous silica, with the separation of these varieties in view. These results indicate that sodium hydrate attacks the crystalline silica most readily, sodium carbonate least readily, but that, all things considered, a 25 per cent. solution of potassium hydrate is the best reagent of the three to effect a separation of the amorphous silica from the crystalline variety. For this purpose the mixture is boiled

with 100 cc. of the solution for one hour. The results of the analyses of diatomaceous earths, as given in the article, afford no clew to the worth of the process. The author makes no reference to the recent work by Michaëlis (*Chem. Ztg.*, 19, 1422, 2002) and Lunge (*Ztschr. angew. Chem.*, 1895, 593), in which conclusions differing materially from his own are reached.

A Source of Error in the Determination of Phosphoric Acid by the Citrate Method. By Francis Bergami. *J. Franklin Inst.*, 141, 383–385. — The author finds that high percentages of phosphoric acid are found if the magnesium-ammonium phosphate be not filtered from the solution containing the citrate without any considerable delay. On standing, the precipitate is contaminated by silica, iron, and alumina. A sample of South Carolina rock, which, according to the molybdate method, contained 16 per cent. of phosphoric acid, yielded apparently 16.96 per cent. when the precipitate of magnesium-ammonium phosphate was allowed to stand fifteen hours, while the analysis showed 15.92 per cent. when the filtration took place after two hours. Only in the determination of water-soluble phosphoric acid, of superphosphates, or the insoluble phosphoric acid of animal phosphates is it safe to allow the magnesia precipitate to remain in the citrate solution for any length of time. The use of concentrated sulphuric acid as a solvent failed to lessen the difficulty.

The Standardizing of Normal Acid by Borax. By Francis Bergami. *J. Franklin Inst.*, 141, 386. — The author recommends the use of "larmoid" as an indicator (by which lacmoid is presumably intended) instead of methyl orange or litmus, as is commonly suggested. The reference to Thomsen's work with this indicator is incorrect as printed; it should be *Chem. News*, 52, 18.

The Estimation of Pyrrhotite in Pyrites Ores. By Edward K. Landis. *Eng. Min. J.*, 61, 349. — Instead of the magnetic separation proposed by Cone (*this Rev.*, 2, 46) the author recommends the determination of the total sulphur and the amount of the mixture of pyrite and pyrrhotite, from which an indirect determination may be made of the amount of each constituent present. It is claimed that the results so obtained represent a closer approximation to the truth than the magnetic method. It seems to the reviewer that the time consumed would be greater than by the magnetic method, with possibility of errors which would influence the final results materially. Any sulphur in combination with copper is apparently included in that assumed to be in combination with the iron as pyrite or pyrrhotite.

Proximate Analysis.

E. H. Richards, Reviewer.

Standard Prisms in Water Analysis and the Valuation of Color in Potable Waters. By A. R. Leeds. *J. Am. Chem. Soc.*, 18, 484–491. — After some statements in regard to the use of glass wedges for color comparisons the author makes the excellent suggestion that a unit of depth of 8 inches should be agreed upon, and a unit of color given in this depth by 0.01 mg. of nesslerized ammonia should be retained as a standard, whatever solutions or glasses are adopted for daily use.

Normal Distribution of Chlorine. By HERBERT E. SMITH. *Ann. Rep. Conn. State Board of Health*, 18. — The geographical position of Connecticut in relation to Massachusetts is such that the determination of the isochlors or lines of normal chlorine in unpolluted waters is of the utmost importance, and these results confirming as they do those obtained for Massachusetts go far toward establishing a law.

G. W. ROLFE, REVIEWER.

Determination of Lactose in Milk by Double Dilution and Polarization. By H. W. WILEY AND E. E. ELWELL. *J. Am. Chem. Soc.*, 18, 428–433. — This paper deals with improvements in Wiley's optical method of determining lactose in milk (*Am. Chem. J.*, 6, 289). The error due to the volume of the precipitated casein is eliminated by the Scheibler double dilution method. The authors, however, deduce by calculation a slightly different formula from that used by Scheibler, viz.: "The true polarization as determined by double dilution is found by dividing the product of the two readings made from the solutions in the large and small flasks by their difference." A more dilute solution of mercuric nitrate is used for clarifying than that recommended in the original paper, and there are other slight modifications of the method. A dozen or more analyses are given which prove the accuracy of the process.

On Two Errors in Sugar House Analyses. By EDMUND C. SHOREY. *J. Am. Chem. Soc.*, 18, 462–465. — The author calls attention to the error in fiber determinations caused by varying the amount of water and time of boiling, and shows that it may exceed 1 per cent. of the weight of the cane. He suggests that comparative results be obtained by chemists using a uniform method. In his own practice the author dries the residue from alcoholic extraction and calls this fiber. — In the determination of albuminoids in cane juice the author states that any method in which the juice is heated gives unreliable results, and gives data to prove this.

J. F. NORRIS, REVIEWER.

On the Action of Wagner's Reagent upon Caffeine and a New Method for the Estimation of Caffeine. By M. GOMBERG. *J. Am. Chem. Soc.*, 18, 331–342. — Contrary to previous statements, the author finds that Wagner's reagent can be used for the analysis of caffeine, as it gives with the latter a characteristic precipitate. This is obtained by using either caffeine or iodine in excess and by employing different acids, and always has the composition $C_8H_{10}N_4O_2.HI.I_4$. This periodide is a violet-blue amorphous powder, melting at 213°, which crystallizes from methyl alcohol in six-sided prisms with a metallic dark-bluish luster. The precipitate is formed in very dilute solutions of caffeine if acid is present. To make a quantitative determination, a definite volume of a solution of caffeine, acidulated with one fiftieth of its volume of concentrated sulphuric acid, is precipitated with a known amount of iodine in potassium iodide. After a considerable excess of iodine has been added, an aliquot portion of the supernatant liquid is titrated with sodium thiosulphate. The results are accurate within one per cent. The method for the determination of the alkaloid in a caffeine-bearing drug is described in detail.

F. H. THORP, REVIEWER.

Chemical and Mechanical Analyses of Soils. BY H. SNYDER. *Minn. Agr. Expt. Sta., Bull.* 41, 32–58. — Wishing to test the accuracy of the usual methods of soil analysis, the author prepared a "composite sample" by mixing equal weights of some two hundred different soils. The analysis of this "composite soil" is then compared with the average of the analyses of the individual soils used. The conclusion drawn is that the methods yield very accurate results. A discussion of the value of soil constituents as plant food, together with analyses of some marls and an alkali soil, are also included.

Examination of Oil Meals. BY F. W. WOLL. *Agr. Expt. Sta. Univ. Wis., Ann. Rep.* 12, 64–85. — The article contains tabulated analyses, with accounts of methods employed and of the adulterations found in oil cake.

TECHNICAL CHEMISTRY.

F. H. THORP, REVIEWER.

The Manufacture of Calcium Carbide. BY J. T. MOREHEAD AND G. DE CHALMOT. *J. Am. Chem. Soc.*, 18, 311–331. — This is a description of the process as carried out in the works of the Willson Aluminium Company, at Spray, North Carolina. Descriptions and drawings of the furnaces used there, and also of those to be used by the Niagara Falls carbide plant, are given. The furnaces at Spray, being the first in which calcium carbide has been produced in quantity, have shown many difficulties and weak points which it is thought will be largely overcome in the new King furnace to be used at Niagara Falls. Two furnaces are used at Spray, and they must be allowed to cool before the charge can be removed. This is avoided in the King furnace by making the bottom of the furnace in the form of an iron car, in which the carbide is formed. When full of carbide the car is at once replaced by an empty one without allowing the furnace to cool. The coke used must be as free from ash as possible, and should be ground to pass through a 50-mesh sieve. The lime may be quicklime or air-slaked, but the former is better. It should contain no magnesia, as this does not combine with either carbon or lime and is very detrimental to the production of carbide. The lime need not be so fine as the coke, being passed through a 10-mesh sieve. The materials are very thoroughly mixed, and fed into the furnace as fast as the carbide forms. The carbide constitutes a solid mass of conical shape 2½ feet high in the Spray furnace. It never fills the furnace, and is always surrounded by a loose covering of unchanged lime and coke dust, which falls away from the lump of carbide on removing it from the furnace. Pure carbide yields 5.9 cu. ft. of gas per pound, but it is found more economical to make carbide yielding about 5 cu. ft. of gas per pound. For this 100 parts of lime and 64 or 65 parts of carbon are mixed and subjected to a current of 65 volts and 1,700 to 2,000 amperes. For 100 volts somewhat more carbon is needed. High voltage necessitates more frequent emptying of the furnace, and the cone of carbide formed is very slender. Theoretically 0.563 lb. of carbon and 0.875 lb. of calcium oxide are needed to form 1 lb. of carbide, but in practice some lime and carbon are lost by volatilization. The average of ten experiments showed 1.228 lbs. calcium oxide, and 0.837 lb. of carbon were used in producing 1 lb. of carbide. By keeping the arc covered

with the mixture of lime and coke some loss is prevented. Trials of charcoal, anthracite, and bituminous coal showed these to be unsuitable, the first because of its high price and light weight, much being carried out of the furnace by the gases. Coke gave the best result. It is claimed that, including interest, wear and tear, etc., the Spray works can produce carbide at less than $25 per ton. Tabulated results of eight series of experiments, and descriptions of the analytical methods used to control the running of the works, are included in the article.

A Hypothetical New Hydraulic Cement. By A. D. Elbers. *Eng. Min. J.*, 61, 373–374. — The author first considers the theoretical aspects of the causes of hardening in hydraulic mortars and cements. He holds the opinion that this hardening is due to the presence of amorphous silica or soluble alkaline silicates, or both, together with lime which is set free during the hydration of the cement. These substances react on each other to produce hydrated silicates of lime, which are probably amorphous at first, but become crystalline on continued exposure to water, and to this crystallization the hardening is due. The author then considers the new cement to be produced from blast-furnace slag of a certain composition. The slag must be desulphurized while in the molten state, and cooled suddenly to prevent crystallization of its silica. A consideration of the causes of "blowing" and "slacking" in the burned material for Portland cement follows. The author also takes the view that alumina, while playing an important part in the formation of the "frit" for Portland cement, is not essential to a cement produced from a fused mass such as slag, nor does it enter into the reactions of the setting or hardening of the cement with water. In his opinion induration must be ascribed chiefly to the formation of hydrated silicates of lime.

Metallurgical Chemistry.

H. O. Hofman, Reviewer.

Treatment of Zinc-Lead-Sulphide Ores. By F. L. Bartlett. *Eng. Min. J.*, 61, 492. — The author has treated during the last five years sulphide ore carrying 20 to 25 ounces silver per ton, 15 to 25 per cent. lead, 25 to 35 per cent. zinc, at Cañon City, Colorado, at a cost ranging from $4 to $7 per ton. He concentrates the silver with the copper in an iron matte, and volatilizes most of the lead and zinc, which are collected and form a marketable product.

The Morosco Fusion Process. By R. P. Rothwell. *Eng. Min. J.*, 61, 495. — This process is a revival of the attempt to extract precious metal from finely pulverized ore by passing it through a bath of lead. A plant has been worked since April, 1896, at the Bunker Hill mill, Amador County, California, treating from 10 to 20 tons of ore that have been crushed through a 30 to 40-mesh sieve and dead roasted. The ore, red-hot from the furnace, is made to ascend through the lead bath. On leaving it, freed from silver and gold, but having taken up about 44 per cent. of lead, it drops into a water box and passes over concentrators, which recover the lead in the heads to be smelted in the usual way. It is claimed that gold-bearing sulphurets can be worked at a cost of $3 to $4 per ton, with an extraction of over 90 per cent.

Matte-Smelting. By W. L. Austin. *Min. Sci. Press*, 77, 245, 288, 356–357, 376–377. Reply by H. Lang. *Ibid.*, 77, 417–418. — The first named author deprecates the use of a new terminology by H. Lang in his treatise on "Matte Smelting," and prefers to base his nomenclature as much as possible on accepted terms. In comparing the ordinary blast furnace smelting with carbon as fuel, and pyritic smelting with pyrite as fuel, he brings out the leading differences, and argues (1) that it is not advisable to mix up the two processes, as Lang does in his "Gradual Reduction Process" (*Tech. Quart.*, 8, 113), where sulphides are smelted in an oxidizing atmosphere with the use of a small percentage of carbonaceous fuel, the gradual oxidation of iron and sulphur furnishing the bulk of the heat required; (2) that the general type of blast furnace used in lead smelting, viz., a high furnace with contracted tuyere zone, is not suited for pyritic smelting; (3) that brick furnaces are to be condemned in every instance where there is enough water to run a water-jacket blast furnace, an opinion which Wethey (*ibid.*, 398) supports. — Lang answers the above criticism, and in doing this describes the work he is doing at Keswick, California. The ore mixture treated consists of sulphides, oxides, and gold-bearing quartz (in the proportions 4 : 2 : 1½), foul slag and scrap matte. It is smelted in a brick blast furnace 180 by 36 inches at the tuyeres and 90 inches high from tuyeres to throat (72 inches being preferable); the brickwork, which is cooled by water pipes, rests on a steel jacket 12 inches high. From 125 to 140 tons ore mixture are smelted with from 2 to 3 per cent. coke (wood being occasionally used) and a blast of 5 ounces pressure and 500° F., the concentration being 4 tons sulphide into one of matte. The slag is collected in four-wheel pots (holding about 1,500 pounds), which are run into a brick chamber (over 100 feet long), and, passing through it slowly, give up their heat to the blast going in the opposite direction.

Notes on the Hydrometallurgy of Gold and Silver. By W. G. Waring. *Eng. Min. J.*, 61, 447–448. — The author, for many years engaged in leaching silver ores, notes some observed facts not recorded in books, or at least not generally known. — In chlorodizing roasting he has done successful work with the muffle furnace, using the regenerative principle. Such a furnace at Silver City, New Mexico, with a hearth 16 by 40 feet, chlorodized satisfactorily, at an even temperature of 500° C., from 12 to 25 tons ore and concentrates containing from 10 to 30 per cent. sulphur, the temperature of the gases escaping from the muffle hardly exceeding 100° C. The loss in silver as influenced by the size of the mineral particles is given from experience with Northern Sonora quartzose ore containing antimony sulphide but free from copper. If passed through a 16-mesh sieve and roasted with 10 per cent. salt, 96.4 per cent. silver were extracted and 3.4 per cent. remained in the tailings; hence the volatilization loss was very small. With a 30-mesh sieve the figures were: Extraction, 86.3 per cent.; in tailings, 2.7 per cent.; volatilization loss, 11 per cent.; with 45-mesh, left in tailings again, 2.7 per cent., but volatilization loss, 42 per cent. — In leaching the author recovered precious metals from the first and second wash waters, and from the first (very dilute) hyposulphite solution by collecting them in one tank, when silver and cuprous hyposulphite separated out. After decanting the supernatant water the salts were charged into a vat in which hypo-leaching was nearly finished, when the floating sulphides readily converted the copper into insoluble sulphide, while the hyposulphite solution dissolved the silver salt. — As regards certain chemical points in leaching, the author calls attention to the fact that ferrous sulphate and sodium sulphite do not act upon silver chloride dissolved

in brine, but that manganous and ferrous hydroxides (?) in alkaline solutions make silver insoluble. He corrects their bad effects by adding ferric chloride (prepared from green vitriol, bleaching powder, and sulphuric acid), which he has found to be more effective than Russell's acidulated blue vitriol; it also has the advantage of not introducing copper into the sulphides.

An Improved Process for Extracting Gold Ores. By W. M. Grosvenor. *Eng. Min. J.*, 61, 424–425. — A patented process which claims to combine all the advantageous features of stamp-milling, chlorinating, cyaniding, and electrolyzing.

The Cassel-Hinman Gold and Bromine Process. By P. C. McIlkiney. *J. Am. Chem. Soc.*, 18, 451–456. — The author gives a general review of the extraction of gold by smelting, amalgamating, and leaching processes; he then extols the advantages of bromine over chlorine in leaching gold ores, and outlines the Cassel-Hinman process, which consists in the recovery of bromine from gold bromide solution previous to precipitating the gold as sulphide. The advantages claimed for bromine as compared with chlorine are greater solubility in water (Br : Cl = 3.2 : 0.76), smaller oxidizing power for pyrite, and greater solvent power for gold. — The Cassel-Hinman process consists in adding to the gold bromide solution some oxidizing agent to liberate the bromine and in distilling it off by means of steam. The oxidizing agents recommended are chlorine or bleaching powder and acid, potassium permanganate and acid. The latest improved still is a covered stone tank, with outlet for vapors leading into stoneware condensers. With a solution containing 15 pounds bromine in 100 gallons of water only 5 gallons need be distilled over to recover about all the bromine. The objection that bleaching powder and acid might just as well be used on ore is met by the fact that in treating the solution alone only a small amount of reagent is required to decompose the bromide, while the reverse would be the case with ore.

Is Potassic-Zinc Cyanide a Solvent for Gold, or is Potassic-Auro Cyanide a Solvent for Zinc? By E. B. W. *Eng. Min. J.*, 61, 443. — A continued discussion by the author in reply to J. C. Wells' criticism (this *Rev.*, 2, 27).

The Cyanide Process at the Mercur Mill. By B. E. Janes. *Min. Sci. Press*, 72, 418–419. — This is a description of the ore, the mill, and the method of working. The ore is crushed very coarsely only, as it disintegrates sufficiently when it comes in contact with water in leaching tanks. The method of leaching is of special interest. It consists in alternately covering the ore with solution and allowing it to drain off, the operation lasting three hours and being repeated from eighteen to twenty times. Formerly the solution was kept running continuously through the ore. With the present method the extraction of gold is higher and the time required from one third to one half less. Professor Christy believes the better results are due to the more perfect draining off of solution out of the interstices of the clayey ore and to the greater abundance of oxygen.

The Electro-Metallurgy of Aluminum. By J. W. Richards. *J. Franklin Inst.*, 141, 357–381. — The author, as an introduction to his lecture, gives a simple and clear exposition of the field covered by electro-metallurgy,

and takes up the leading characteristics of the principal aluminum minerals and compounds. The subject is discussed under three heads: 1. Electrolysis of Aqueous Solutions. The reasons are concisely set forth why this method of electrolytic reduction has not been a success, as well as the possibilities of its application to the refining of impure aluminum. 2. Electrolysis of Fused Compounds. The refining of crude metal by the use of fused chlorides and fluorides as flux and its future prospect from an economic point of view are briefly discussed. This is followed by a short illustrated description of the Hall process as carried out at New Kensington, Pennsylvania, and Niagara, New York; of the Hiroult metal process as found at Neuhausen (Switzerland), and the same process at Froges (Isère, France). These are the leading works in operation to-day. They represent 11,700 horse power, with a daily capacity of 14,900 pounds aluminum. The capacity of these plants is being increased and two new ones are being built, which will make in 1897 or 1898 a total of 33,000 horse power, corresponding to a daily capacity of 42,500 pounds aluminum, or an annual capacity of 7,650 tons. 3. Electro-Thermal Processes. A short review of the Cowles and Hiroult alloy processes, with reasons for abandoning them, closes the paper.

Geological and Mineralogical Chemistry.

W. O. CROSBY, REVIEWER.

Notice of Some Syenitic Rocks from California. BY H. W. TURNER. *Am. Geol.*, 17, 375–388. — In his introduction the author argues in favor of basing the classification of rocks more strictly upon the quantitative mineral and chemical composition, without regard to their structure, age, or the mode of their occurrence, and by way of illustration gives in detail the great division of the feldspathic rocks, to which the syenites belong. The account of the syenitic rocks of California which follows is accompanied by fifteen chemical analyses of the different types, but the analyses are not discussed.

The Geology of the Little Rocky Mountains. BY WALTER HARVEY WEED AND LOUIS V. PIRSSON. *J. Geol.*, 4, 399–428. — The Little Rocky Mountains resemble a wooded island, rising 2,000 to 3,000 feet above the treeless plains of Central Montana. They are formed by a dome-shaped uplift exposing Archæan and Paleozoic rocks in a region of nearly horizontal Cretaceous strata. The uplift has its origin in a great laccolitic intrusion of granite porphyry, and this is the feature to which the authors give chief attention. The elaborate petrographic discussion of the igneous rock is accompanied by a complete analysis by Dr. H. N. Stokes. The striking feature of the analysis is the exceedingly small percentages of lime, iron, and magnesia. In spite of the presence of oligoclase the rock clearly belongs in the alkali series. Had more iron and magnesia been present the lime would have been partly exhausted by the production of augite or hornblende. Their absence has forced it into the feldspars. Their absence also explains why with a high silica percentage but little quartz is present.

The Bearpaw Mountains, Montana. BY WALTER HARVEY WEED AND LOUIS V. PIRSSON. *Am. J. Sci.*, 151, 283–301, 351–362. — This paper gives an account of the prominent features of a mountain group in northern Montana. It consists of a cluster of dissected volcanoes whose brec-

cias, tuffs, and flows compose a large part of the area, especially the marginal region, while cores of massive rock and associated dikes and bosses are found cutting soft Cretaceous shales in the central parts of the mountainous tract. The rocks present interesting examples of the differentiation of an alkaline magma, and consist of various types of the syenite family of igneous rocks, together with highly differentiated basic forms that accompany them. Four complete analyses of the principal types, by Dr. H. N. Stokes, are given, and many other analyses are quoted for comparison.

On the Occurrence of Pollucite, Mangano-Columbite, and Microlite at Rumford, Maine. By H. W. Foote. *Am. J. Sci.*, 151, 457–461. — Pollucite, a rare silicate of aluminum and cæsium, with the formula $H_2Cs_4Al_4(SiO_3)_9$, had previously been discovered at only one locality in the United States (Hebron, Maine). The analyses from which the above formula is derived agree very closely. The striking resemblance of the mineral physically to vitreous quartz suggests that it may be less rare than heretofore supposed, having been overlooked by collectors. Quantitative analyses of the other minerals named in the title were not made.

The White Phosphates of Tennessee. By C. W. Hayes. *Trans. Am. Inst. Min. Eng.*, 25, 19–28. — These phosphates are in Perry County, near the Tennessee River, and two types are recognized, the white breccia and the white bedded. Both are believed to be essentially superficial and in origin secondary or residuary with reference to the associated limestone and shale. Six chemical analyses of the second type show from 27.40 to 33.40 per cent. of lime phosphate, $Ca_3P_2O_8$.

The Tin-Deposits of Durango, Mexico. By W. R. Ingalls. *Trans. Am. Inst. Min. Eng.*, 25, 146–163. — A historical sketch of discovery and development is followed by a brief account of the geology of the deposits. The country rocks are acid volcanics (rhyolite and rhyolite tuff), deeply decomposed, in which the cassiterite occurs as extremely irregular and bunchy impregnations and replacements, the original source of the tin oxide being still doubtful. The chief associated minerals are hematite, quartz, hyalite, chalcedony, fluorite, and topaz, the last in fine crystals of various colors. There is no evidence of wolfram compounds either in the ore or in the metal smelted from it, but analyses of the pig tin developed the very remarkable fact that it contains from 7.31 to 9.29 per cent. of metallic antimony. The absence in the ore of any independent antimony-bearing minerals distinguishable by the eye indicates that the antimony is probably chemically combined with the cassiterite, as the late Dr. Genth has shown to be the case with arsenic in certain Mexican tin ores. Twelve analyses of the Mexican tin ores are quoted from Genth.

Corundum of the Appalachian Crystalline Belt. By J. Volney Lewis. *Trans. Am. Inst. Min. Eng.*, 25, 852–906. — The chief corundum deposits are found in connection with peridotite (olivine rock or dunite), but closely associated with this are pyroxenites, amphibolites, and secondary rocks. The pyroxenites include both enstatite rock and websterite. The essential mineral of the first named variety having been frequently called anthophyllite, a typical example was analyzed, and proved to be normal enstatite, with an iron percentage which places it near the bronzite variety. Similarly among the amphibolites the bright grass-green mineral heretofore called smaragdite was proved by analysis to be a true hornblende and to owe its exceptional color to a small proportion of chromium.

The Monoclinic Pyroxenes of New York State. By Heinrich Ries. *Annals New York Acad. Sci.*, 9, 124–178. — This is an exhaustive monograph of a narrow mineralogical group. In the section on the relation between the optical and chemical properties it is shown that the extinction angle does not increase with the percentage of FeO, as supposed by Wiik, but rather with the sum of the percentages of FeO, Fe_2O_3, and Al_2O_3. The axial angles show a similar but less definite relation to the sum of the iron oxides and alumina. Bright crystals of diopside and augite were treated with warm hydrofluoric acid, and the resulting etch figures are illustrated and discussed. Original analyses of each variety for all its principal localities are given, and the writer has attempted in each case to calculate the mixture of metasilicates present. In all the analyses the material was first purified by treatment of the fine powder by a magnet and afterwards with a specific gravity solution. Tschermak's theory that in the alumina-free augites Ca = Mg + Fe, while in the aluminous ones Ca < Mg + Fe, is shown to hold good in the case of only about one half of the New York pyroxenes analyzed. Uralitization, or the paramorphic change of pyroxene to amphibole, is the almost universal mode of alteration; but the writer also discusses the alteration to serpentine, which depends upon the assumption of water and loss of lime, and to chlorite, pink garnet, and mica (clintonite).

Geological Survey of Iowa. *Ann. Rep.*, 4 (1895). — This volume embraces detailed descriptions of the geology of six counties. Particular attention is given to the economic geology, and under that head are introduced several analyses of the coals of the State (pp. 219 and 411), and also analyses of cone-in-cone (p. 231), loess (glacial clay) (p. 357), and soils (p. 229).

Preliminary Report on the Marquette Iron-Bearing District of Michigan. By C. R. Van Hise and W. S. Bayley. *U. S. Geol Surv., Ann. Rep.*, 15 (1893–94), 477–650. — This is an advance and summary publication of an elaborate monograph on the oldest important iron-producing area of the Lake Superior region. It is essentially a structural study, and the petrographic descriptions are only rarely accompanied by chemical analyses of the rocks, including the Kitchi schists, serpentine, peridotite, sideritic slate, jaspilite, and grünerite-magnetite schist.

The Origin and Relations of Central Maryland Granites. By C. R. Keyes. With an Introduction by G. H. Williams. *U. S. Geol. Surv., Ann. Rep.*, 15 (1893–94), 651–740. — In this very important and complete petrographic study chemical analysis has aided materially in the determination of the origin and relations of the rocks. As if by way of specially illustrating this point, Professor Williams gives analyses of three representative specimens of a series of doubtful but similar gneissoid rocks. An examination of these analyses shows that in spite of their decided gneissoid structure two of the rocks are essentially basic granites in composition, while the third has no relation to any known igneous type, but agrees closely with certain siliceous sediments and must be regarded as of sedimentary origin. In all twenty-two analyses of the granites and more basic rocks associated with them are given, although a good proportion of these have appeared in earlier publications. One of the most interesting and novel mineralogical features of the granites is the occurrence of epidote as an original constituent, and an analysis of the epidote is introduced to more fully establish its identity. Other analyses throw light upon the alteration of limestone inclusions in the granites.

The Iron Ores of Nictaux, Nova Scotia, and Notes on Steel Making in Nova Scotia. By E. GILPIN, JR. *Proc. and Trans. Nova Scotia Inst. Sci.*, 9, 10–20. — A brief history of steel manufacture and its introduction into Nova Scotia is followed by an account of the iron ores of the Nictaux district and a series of analyses of the principal beds, the analyses showing, among other things, that this district produces no Bessemer ores.

Notes on the Kaolin and Clay Deposits of North Carolina. By J. A. HOLMES. *J. Elisha Mitchell Sci. Soc.*, 1895, part second, 1–10; and *Trans. Am. Inst. Min. Eng.*, 25, 929–936. — The author gives a general account of the pegmatite dikes of Western North Carolina and the bodies of kaolin which result from their superficial alteration. A chemical analysis representing the most important deposit now worked shows a close approximation to the theoretical composition of kaolin. The transported or sedimentary clays of the central and eastern sections of the State are next described, and an analysis is given of a so-called fire-clay from the Eocene formation, which shows: Silica, 87.70; alumina, 3.29; ferric oxide, 2.81; lime. 0.48; magnesia, 0.40; alkaline chlorides, 1.48; loss on ignition, 3.15 = 99.31. It is evidently an aluminous fire-sand rather than a fire-clay.

BIOLOGICAL CHEMISTRY.

Sanitary Chemistry.

E. H. RICHARDS, REVIEWER.

The Chemical Composition of American Food Materials. *U. S. Dept. Agr., Expt. Sta. Bull.* 28, 1–47. — These tables give in a compact form data which have hitherto been wanting or which were so scattered through a mass of publications as to render them more or less inaccessible. The composition of American dishes, such as pie and doughnuts, cake and cookies, will be very useful to the teacher of domestic science, who has been at great disadvantage in being obliged to use only German tables. Both fresh and dried fruits enter so largely into the food of even poor families and institutions that the analyses of these will prove of great service in comparisons of dietaries.

Zinc in Evaporated Apples. By H. W. WILEY. *U. S. Dept. Agr., Div. Chem., Bull.* 48, 1–38. — This is one of the most interesting as well as practically useful bulletins ever issued. That an American food product should be condemned in Germany as containing zinc in such quantities as to be prejudicial to health is a sufficiently startling statement to demand the attention of the government. The presence of zinc in a large part of the yearly output arises from the fact that the apples have been dried on trays of galvanized iron wire. An immediate change to tinned wire or to perforated aluminum is recommended. The question as to how far small quantities of zinc (in this case about 0.01 per cent.) can affect the health is still unsettled. In the description of the methods in general use of preparing the apples for market the practice of sulphuring or bleaching the fruit is mentioned. This is of interest because of the existence on the market of proprietary preparations intended to be used in the household for preserving fruit without cooking and dependent upon sulphurous acid for their efficacy. That this acid does become converted into sulphuric acid is proved, and a pertinent question is how much sulphuric acid is harmful.

Dietaries Studies at the University of Tennessee. *U. S. Dept. Agr., Expt. Sta. Bull.* **29**, 1–45. — This paper is a welcome contribution to our knowledge of the amount, kinds, and composition of the food materials purchased and eaten by companies of students or by families in the South. The one thing yet lacking in all these discussions is accurate knowledge as to the methods of preparation of the food and the influence which this has on the quantity assimilated.

Composition and Digestibility of Corn Ensilage, Cow Pea Ensilage, Soja Bean Ensilage, and Corn Fodder. *Agr. Expt. Sta. Univ. Ill., Bull.* **43**. — In view of the discussion as to the use of the soja bean for human food the results here given have considerable interest. It seems that cow pea ensilage is more digestible than that from the soja bean, a result which might be expected from the fact that the latter contains a higher proportion of cellulose.

Compilation of Analyses of Fruits, Garden Crops, and Insecticides. — By H. D. Haskins. *Hatch Expt. Sta., Mass. Agr. College, Ann. Rep.* **8**, 180–187. — Only a part of the analyses were made at the experiment station, the others being taken from the tables of E. Wolff.

Analyses of Waters. *Cal. Agr. Expt. Sta., Ann. Rep. for* **1894–95**, 92–113. — This contains the results of an extended study of the waters of California.

Water Analyses. By E. E. Slosson. *Expt. Sta. Univ. Wy., Bull.* **24**. — Tabulated results of a large number of analyses of irrigation, spring, and well waters.

Agricultural Chemistry.

F. H. Thorp, Reviewer.

Idaho Soils, Their Origin and Composition. By C. W. McCurdy. *Idaho Agr. Expt. Sta., Bull.* **9**, 1–28. — Analyses of thirty-three soils taken from eight counties are given, and also a classification of the soils of the State.

Analyses of Muck, Marl, and Seaweed. By F. T. Shutt. *Canada Expt. Farm, Rep. for* **1894**, 158–164. — Twenty-four analyses, chiefly of muck, are given, together with some remarks on the use of these substances.

Compilation of Analyses Made at Amherst, Massachusetts, of Agricultural Chemicals and Refuse Materials Used for Fertilizing Purposes. By H. D. Haskins. *Hatch Expt. Sta., Mass. Agr. College, Ann. Rep.* **8**, 163–187. — This is a tabulated review of all analyses made at the experiment station from 1868 to 1896, with the exception of analyses of licensed fertilizers, which are to be found in the regular reports. The analyses have been calculated to pounds per ton of 2,000 pounds in each case.

Sulphate of Ammonia as a Fertilizer. *U. S. Consular Rep.*, 50, 547. — The United States consul at Palermo reports that experiments made with sulphate of ammonia as a fertilizer for the vine and lemon have shown beneficial results in quantity and quality of the fruit.

Observations Concerning the Action of Muriate of Potash on the Lime Constituents of the Soil. By C. A. Goessmann. *Hatch Expt. Sta., Mass. Agr. College, Bull.* 38, 14–16. — This is a preliminary report of some observations on field experiments covering several years. It was noticed that some plats which had been fertilized for several successive years with muriate of potash produced annually decreasing yields and plants of unhealthy appearance. It is concluded that the carbonates of lime and magnesia in the soil may be decomposed by the muriate of potash, and that on a shallow soil with compact clayish subsoil plants may be injured by the chlorides of lime and magnesia collecting near their roots. On soils naturally poor in lime muriate of potash may cause such an impoverishment of this element through its solution that the application of lime becomes essential as a manure.

Marls of Wisconsin. By F. W. Woll. *Wis. Agr. Expt. Sta., Bull.* 51, 1–16. — An account of the occurrence, chemical composition, and uses of marls found in Wisconsin. Analyses of forty-four samples are given. The uses and application of marl as fertilizer, for Portland cement manufacture, for quicklime, and for polishing and scouring powders are discussed.

Alkali and Alkali Soils. The Distribution of the Salts in Alkali Soils. By E. W. Hilgard and R. H. Loughridge. *Cal. Agr. Expt. Sta., Ann. Rep. for* 1894–95, 37–71. — This is an interesting study of the alkali soils of California. A large number of analyses are tabulated and curves plotted showing the distribution of alkali at various depths. The investigation was undertaken with the idea of determining the source of the alkali and of the possibility of removing or neutralizing it. The authors take the view that, as the alkali is chiefly near the surface of the ground, a system of underdrainage and means of preventing surface evaporation will solve the difficulty.

Commercial Fertilizers. *Agr. Expt. Sta. Bull.: Md., No.* 37; *Vt., Nos.* 50, 51, 52; *Wis., No.* 49; *Mass., Hatch Sta., No.* 38; *Me., No.* 25; *Conn., Ann. Rep.* 19; *Miss. State Chemist, Bull. No.* 8; *Cal. Ann. Rep. for* 1894–95, 135–139; *Conn., Bull. No.* 122. — The foregoing bulletins and reports of the several agricultural experiment stations contain tabulated analyses of fertilizers. In each case the name of the brand and of the manufacturer is stated.

Apparatus.

A. H. Gill, Reviewer.

A Simple Form of Gas Regulator. By L. Saarbach. *J. Am. Chem. Soc.*, 18, 511–513. — The apparatus, a cut of which is given, consists of an air thermometer acting upon mercury. It is all in one piece, and is easily filled and cleaned.

The Practical Use in the Chemical Laboratory of the Electric Arc Obtained from the Low Potential Alternating Current. By M. S. Walker. *Am. Gas Light J.*, 64, 610. — The article describes apparatus which can be obtained in almost any laboratory by which some of Moissan's experiments may be repeated in the laboratory upon a small scale. The melting of quartz and reduction of manganese are easy matters.

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EDITED BY ARTHUR A. NOYES.

ANALYTICAL CHEMISTRY.

Ultimate Analysis.

H. P. TALBOT, REVIEWER.

Notes on the Electrolytic Determination of Iron, Nickel, and Zinc. BY H. H. NICHOLSON AND S. AVERY. *J. Am. Chem. Soc.*, **18**, 654–659. — The authors find that in the presence of ammonium tartrate an electrolytic deposit of iron always contains some carbon, the amount increasing with the amount of free ammonia and the strength of current. Carbon was also deposited with the iron from solutions containing sugar, alcohol, glycerol, or salts of acetic, lactic, citric, succinic, or benzoic acids. Formates and oxalates in the absence of other organic compounds gave a deposit free from carbon. From a solution of ferrous sulphate containing 5 grams of citric acid, in the form of sodium or potassium salts, the carbon deposited amounted to 1.9 per cent. of the weight of the iron. Sodium tartrate gave unsatisfactory results. The addition of borax, together with ammonium oxalate, to an iron solution seemed to facilitate precipitation, the operation being completed in the cold with a weak current. In this way a firm coating was obtainable. — Nickel does not carry down carbon, but does not, by its presence, prevent the deposition of the latter with iron. — The oxidation of zinc after deposition may be obviated by the addition of formic acid to the solution. The procedure is not successful in the presence of iron, nickel, cobalt, or the members of the sulphuretted hydrogen group.

Determination of Sulphuric Acid. BY N. J. LANE. *J. Am. Chem. Soc.*, **18**, 682. — Results of experiments are cited which indicate that the rapid addition of barium chloride to a sulphate solution tends to cause percentages above the true figures. (Compare this *Rev.*, **2**, 47.)

Note on the Solubility of Bismuth Sulphide in Sodium Sulphide, with Special Reference to the Estimation of Small Amounts of Bismuth in Anti-Friction Alloys. BY THOMAS B. STILLMAN. *J. Am. Chem. Soc.*, **18**, 683–684. — It was found that bismuth sulphide is not wholly insoluble in sodium sulphide. The treatment of 0.128

NOTE. — The *Review of American Chemical Research* for the year 1896 will not be complete until the publication of Vol. II, No. 4, and index in the *Technology Quarterly* for March, 1897, Vol. X, No. 1. All of the *Review* for 1896, however, should be bound with Vol. IX of the *Quarterly*.

gram of bismuth nitrate, after solution in water and nitric acid, which is subsequently neutralized by sodium hydroxide, with 75 cc. of sodium sulphide solution (1.06 sp. gr.), at a temperature near the boiling point, for twenty minutes, caused the solution of sufficient bismuth by the sodium sulphide to yield 0.031 gram of bismuth trioxide.

On the Estimation of Sulphur in Pyrites. By G. Lunge. *J. Am. Chem. Soc.*, **18**, 685–686. — Additional data are presented by the author which are intended to show that the slow addition of the barium chloride solution, recommended by Gladding, is unnecessary. It is a pleasure to learn that this discussion is to close with this paper. (Compare this *Rev.*, **2**, 47.)

The Quantitative Determination of the Three Halogens, Chlorine, Bromine, and Iodine, in Mixtures of Their Binary Compounds. By A. A. Bennett and L. A. Placeway. *J. Am. Chem. Soc.*, **18**, 688–692. — The mixture of the halogen salts is added to about 50 cc. of a solution of ferric ammonium alum (containing 200 grams per liter), the whole is diluted to 200 cc., and distillation is continued for twenty-five minutes in a distilling apparatus described in detail in the paper. The liberated iodine is collected in a receiver (with potassium iodide), and titrated with sodium thiosulphate. To the solution in the distilling flask 35 cc. of a strong potassium permanganate solution are added, and sufficient water to make a total volume of 200 cc. Distillation is again continued for twenty-five minutes, during which the bromine is driven over into a receiver. The excess of potassium permanganate in the flask is determined by titration with ferrous sulphate, and finally the chlorine is precipitated in the same solution by silver nitrate, or might be determined volumetrically. The heating of the solution while titrating with ferrous sulphate, recommended by the authors, would seem to be an unnecessary source of error, since it both promotes the interaction between the liberated hydrochloric acid and the potassium permanganate, and also between the latter and the manganous sulphate formed. The results of experiments submitted show considerable accuracy as regards iodine, but are less satisfactory with respect to bromine and chlorine. The authors comment upon earlier methods to some extent.

Determination of Iron Oxide and Alumina in Phosphate Rock by the Ammonium Acetate Method. By Thomas S. Gladding. *J. Am. Chem. Soc.*, **18**, 717–721. — The author shows by experiments that iron and aluminum phosphates, precipitated in the presence of calcium, by pouring the weakly acid solution of the three phosphates slowly into a strong solution of ammonium acetate, made acid with acetic acid, and digesting for a short time at a gentle heat, may be freed from the calcium by three successive precipitations, and that during these precipitations no iron or aluminum is lost, provided that an excess of phosphoric acid be added before each deposition. The procedure recommended for phosphate rocks is the following: 4 grams are digested for one half hour with 30 cc. hydrochloric acid (1 : 1), the solution filtered, the iron oxidized with nitric acid, and the solution made up to 200 cc. Of this solution 50 cc. (or 25 cc.) are taken and carefully neutralized with ammonia until a slight precipitate remains when solution is cold. This is redissolved by adding a few drops of hydrochloric acid. The solution is poured in a fine stream into 15 cc. of a strong solution of ammonium acetate (made by neutralizing 30 per cent. acetic acid with strong ammonia) and

5 cc. of acetic acid, and the whole digested for a half hour at 60° C. The filtered precipitate is washed with ammonium acetate solution, dissolved in hot dilute hydrochloric acid (1 : 4), and 1 gram of ammonium phosphate is added. The precipitation is repeated, and also for a third time with the intermediate addition of ammonium phosphate. The precipitate is finally ignited and weighed as the phosphates. The iron is determined volumetrically.

A New Method for the Estimation of Iron Oxide and Alumina in Phosphate Rock. By THOMAS S. GLADDING. *J. Am. Chem. Soc.*, **18**, 721–724. — The procedure differs from that outlined in the preceding abstract in the use of chemically pure potassium hydroxide solution to separate the aluminum. The solution of the phosphate rock, prepared as above, is run into 20 cc. of the potassium hydroxide solution (500 grams per liter), and the whole digested for an hour at 70° C., with occasional stirring. The precipitate is filtered off on a paper filter and washed several times with hot water. The filtrate is acidified with hydrochloric acid; ammonium phosphate is added and the aluminum thrown down as described in the foregoing paper, and weighed as phosphate. The iron may be determined by solution of the precipitated hydroxide, or in an independent portion.

Volumetric Estimation of Lead. By FRED. J. POPE. *J. Am. Chem. Soc.*, **18**, 737–740. — From 0.3 to 0.7 gram of the ore is treated with 4 to 5 cc. of a previously prepared mixture of two parts sulphuric acid, three parts nitric acid (no specific gravity given), and one part water for each gram of ore. It is evaporated as nearly as possible to dryness, cooled, and the dish (a small one) filled with water. The sulphates are filtered off, washed with cold water, and the filter and precipitate transferred to a beaker or flask. The dish, and finally the filter, are treated with boiling ammonium acetate solution, acid with acetic acid, the boiling continuing from seven to ten minutes. The cold solution is neutralized with ammonia, and 100 cc. of decinormal potassium bichromate are added, with stirring. The precipitate is filtered off and washed, and the filtrate made up to a definite volume. Of this an aliquot part is placed in a porcelain dish, 10 to 20 cc. of decinormal arsenious acid solution are added, and a 40 per cent. sulphuric acid solution to acidity, avoiding an excess. After the reduction is completed, the excess of sulphuric acid is neutralized with sodium bicarbonate, and 50 cc. of a saturated solution are added in excess. Starch paste is then added, and the excess of arsenious acid solution determined with decinormal iodine solution. It is noted that a correction should be made for the iodine used up by the 50 cc. of sodium bicarbonate solution. The results of analysis cited are satisfactory.

Estimation of Sulphides in Calcium Carbide. By FRED. J. POPE. *J. Am. Chem. Soc.*, **18**, 740–741. — The carbide is treated with water, in a suitable apparatus, until the evolution of acetylene ceases, after which sulphuric acid is run in and the evolved sulphuretted hydrogen absorbed in lead acetate solution of known strength. After filtering off the lead sulphide, the excess of lead acetate is determined, as outlined in the preceding paper. The author is not prepared to assert that no other products beside hydrogen sulphide capable of affecting lead solutions are evolved. The process is under investigation, and it seems to the reviewer that until its value can be more definitely asserted than seems now to be possible, there is little excuse for its publication.

Aluminum Analysis. By James Otis Handy. *J. Am. Chem. Soc.*, **18**, 766–782. — The paper presents in detail the methods in use in the Pittsburgh Testing Laboratory (Limited) for the analysis of commercial aluminum and many of its alloys. A procedure is given for the determination of silicon (total and graphitic), iron, copper, sodium, carbon, nitrogen, and aluminum in commercial aluminum. The determinations of copper, nickel, manganese, chromium, tungsten, titanium, and zinc (two methods) in their alloys with aluminum are each described, as well as the estimation of tin, phosphorus, and zinc in aluminum solders. The procedure for the analysis of alumina, hydrated alumina, and bauxite is also detailed. The paper, which contributes much valuable information drawn from practical experience, is not of a character which permits of condensation for this *Review*, and reference must therefore be made to the original article for a description of the processes.

Estimation of Thoria. Chemical Analysis of Monazite Sand. By Charles Glaser. *J. Am. Chem. Soc.*, **18**, 782–793. — The paper contains an account of a considerable number of experiments bearing upon the examination of monazite sand and the determination of thoria, from which an analytical procedure has been planned, the essential features of which are as follows: The finely powdered sand is heated with strong sulphuric acid, and the residue, if any, fused with acid potassium sulphate. Silica is rendered insoluble by the sulphuric acid, and when the solution is poured into ice water, there may remain with the silica some tantalic and titanic acids, and traces of thoria and zirconia. The silica is volatilized with hydrofluoric acid, and the residue treated with hydrofluoric and sulphuric acids. Only tantalic acid remains. The solution is saturated with sulphuretted hydrogen — first while hot, then in the cold — and the titanic acid is removed with the sulphides. After removal of the sulphuretted hydrogen from the filtrates, it is nearly neutralized with ammonia, and to the boiling liquid 100 cc. of a cold saturated solution of ammonium oxalate are added for each 2 grams of the sand taken for analysis, and the mixture is allowed to cool over night. The precipitate contains the thoria and the oxides of the cerium group. To separate the thoria, the oxalates are reduced to oxides by ignition, then converted to sulphates, the excess of acid nearly neutralized by ammonia, and boiling ammonium oxalate added in excess to the boiling solution. After a time, but before the liquid has cooled, a few cubic centimeters of ammonium acetate solution are added. When the solution is cold the cerium metals will have precipitated, leaving the thoria. The latter may be thrown down by ammonia from the filtrate and ignited. The separation of cerium from lanthanum and didymium is accomplished by passing chlorine through the liquid containing the freshly precipitated hydroxides. From the filtrate from the original oxalate precipitate the metals are thrown out by ammonia, except part of the alumina, and the phosphoric acid also remains. The precipitate is washed and fused with alkali carbonate. The water solution is added to the filtrate from the precipitate produced by ammonia. The oxides and carbonates are dissolved as sulphates and, except the calcium, are thrown down by ammonia. The filter is incinerated, the residue treated with hydrochloric acid, the solution nearly neutralized with ammonia and poured into a mixture of ammonium carbonate and ammonium sulphide, whereby iron and manganese are thrown down; zirconium, yttrium, and glucinum remain in solution. The carbonate solution is then acidified, the carbon dioxide expelled, the solution cooled, and treated with sodium hydroxide in excess. Glucinum alone remains in solution, and may be pre-

cipitated by boiling for an hour. The zirconium may be separated from the yttrium by dissolving the hydroxides in hydrochloric acid, warming, and saturating with sodium sulphate. The zirconium separates, while the yttrium may be thrown out from the filtrate by ammonia. — Attention is called to the fact that if thorium oxalate, which has been held in solution by ammonium acetate, be thrown down by ammonia, the earth cannot be again completely precipitated by ammonium oxalate from a nearly neutral solution, even if the oxalate has meanwhile been destroyed by ignition. The solubility of the thorium in liquids containing sodium and potassium salts is also increased. It is proposed to investigate this peculiar behavior.

The Effect of an Excess of Reagent in the Precipitation of Barium Sulphate. By C. W. Foulk. *J. Am. Chem. Soc.*, **18**, 793–807. — The paper presents a long series of experimental data, from which the author draws conclusions as follows: For the successful precipitation of barium by sulphuric acid in the presence of hydrochloric acid a considerable excess of the sulphuric acid should be added, and this should be increased with increasing amounts of hydrochloric acid, or when the time of standing is to be shortened. In the presence of a large excess of sulphuric acid the precipitate is coarsely crystalline and easily filtered. For the complete precipitation of sulphuric acid by barium chloride in the presence of hydrochloric acid, a considerable excess of barium chloride is necessary, which must also be increased with any increase of the hydrochloric acid. The precipitate is more coarsely crystalline in the presence of considerable quantities of hydrochloric acid, but precipitation should then take place in concentrated solutions, which occasions contamination with barium chloride. The author claims that the chloride may be removed by repeatedly boiling the ignited sulphate with water. The reviewer would point out that the results are in complete agreement with the laws of solubility effect, which require that barium sulphate should be less soluble in the presence of an excess both of barium and of sulphate-ions. Attention may also be called to the fact that an article presenting substantially the same results has been published almost simultaneously by Fresenius and Hintz (*Ztschr. Anal. Chem.*, 35, 170).

The Actual Accuracy of Chemical Analysis. By Frederic P. Dewey. *J. Am. Chem. Soc.*, **18**, 808–818. — The paper presents a compilation of data drawn from several sources and relating to various commercial analyses, which show the variations in the results of analyses by various chemists of the same sample of material. The analyses include those of manganese in steel; phosphorus in pig iron; copper, gold, and silver in copper materials; phosphoric acid; and potash. No general conclusions of importance are drawn.

An Iodometric Method for the Determination of Carbon Dioxide. By I. K. Phelps. *Am. J. Sci.*, **152**, 70–74. — The carbonate is placed in a flask of about 75 cc. capacity, through the stopper of which passes a separating funnel and exit tube. The latter passes, also, through the stopper of the absorption flask (an ether wash bottle serves well for this purpose) and ends in a Kreider valve (*Am. J. Sci.*, **50**, 132). The absorption flask is connected with a Will and Varrentrapp absorption apparatus. The absorption flask is charged with an amount of barium hydrate solution 7 to 10 cc. in excess of the theoretical requirement, and the absorption bulbs are filled with a solution of potassium iodide to retain any volatilized iodine. Before the

evolution of the carbon dioxide the apparatus is partially exhausted, the pressure being reduced to about 300 mm. A solution of phosphoric acid is then run into the evolution flask and the carbon dioxide completely driven over by boiling for five minutes. The absorption flask is cooled and frequently shaken. After the boiling in the evolution flask has ceased, the atmospheric pressure is restored in the apparatus, and the contents of the absorption flask is boiled for a few minutes. A standardized solution of iodine is then introduced into the absorption flask from a separatory funnel reaching below the surface of the liquid. When the iodine appears to be present in slight excess the liquid in the flask is again boiled. If the color disappears a second small portion of iodine is added, and the boiling is repeated. Finally iodine is added to a deep red, and the excess is determined by titration with arsenious acid. The amount of carbon dioxide is determined from the amount of the barium hydroxide solution destroyed by it. The iodine forms barium iodate and iodide from the excess of the barium hydroxide, but a boiling temperature is necessary to insure the decomposition of any hypoiodite which may form as an intermediate product. It was found that unless the solutions containing the barium carbonate were boiled before the introduction of the iodine, a slight interaction took place between the two. Every precaution must be taken to remove carbon dioxide from the air and water introduced into the apparatus.

The Iodometric Estimation of Molybdic Acid. By F. A. Gooch and Charlotte Fairbanks. *Am. J. Sci.*, **152**, 156–162. — The results obtained by Manro and Danesi (*Ztschr. Anal. Chem.*, **20**, 507), by digestion of the molybdic acid with potassium iodide and hydrochloric acid, both in the cold and in sealed tubes, at 100°, were confirmed by the authors, and the somewhat unsatisfactory results obtained with large amounts of molybdic acid when treated in the cold are ascribed to the influence of the liberated iodine, which occasions a partial reversal of the reaction. To obviate this the authors proposed to remove the liberated iodine by distillation, a procedure which was meanwhile published by Friedheim and Enler (*Ber.* **28**, 2066), and by which one atom of iodine is liberated for each molecule of molybdic acid. Gooch and Fairbanks consider it essential that the duration of the distillation should be more sharply defined than is the case in the article referred to, and find it practicable to start with an initial volume of 40 cc. and to distill off 15 cc. A greater concentration causes a secondary reduction of the molybdenum. The use of an atmosphere of carbon dioxide, from which oxygen is excluded with great care, is prescribed, and the amount of potassium iodide employed for the reduction must be limited to a weight not over one-half gram in excess of the theoretical amount. When the amount of molybdic acid is less than 0.3 gram the total quantity of iodide used should not exceed 0.5 gram. A third procedure, suggested to the authors by the tendency of the molybdenum to reoxidize in the Manro and Danesi process, was worked out as follows: The molybdic acid, or a weight of the molybdate containing from 0.1 to 0.3 gram molybdic acid, together with 0.5 gram potassium iodide, 20 cc. of water, and 20 cc. of hydrochloric acid (1.2 sp. gr.) are placed in a 100 cc. Erlenmeyer flask, and boiled from a total volume of 40 cc. to one of 25 cc. The solution is diluted at once. The solution, while still acid, is but little affected by atmospheric oxygen, but oxydizes rapidly when alkaline. Accordingly, the reduced solution, with a gram of tartaric acid (to prevent precipitation), is placed in a liter flask, sodium hydroxide added to partially neutralize the acid, and sodium acid carbonate to alkalinity, after

which standard iodine solution is run in without any delay. The flask should be set away out of sunlight during one or two hours, after which the excess of iodine is determined by arsenious acid. The formation of a small amount of iodate is possible. To detect and provide for this it is advisable to acidify the solution and titrate for any liberated iodine with thiosulphate. The experimental data cited are very satisfactory.

Insoluble Phosphorus in Iron Ores. By C. T. Mixer. *Eng. Min. J.*, **62**, 4. — The author finds that the fusion with sodium carbonate of any residue which may be insoluble in acids may be replaced by simple calcination at a red heat for a few minutes. By this treatment the phosphoric acid is rendered soluble, and may be extracted by hydrochloric or nitric acid and the solution so obtained added to the main solution. By this procedure considerable time may be gained.

Effect of Varying Acid in Cyanide Determination of Copper. By F. N. Flynn. *Eng. Min. J.*, **62**, 51. — Experimental data are presented to show that the statement made by C. and J. J. Beringer, in their *Text-Book on Assaying*, to the effect that the amount of nitric acid added in the cyanide copper determination is, within reasonable limits, immaterial, is not correct. It is pointed out anew that the conditions must be the same, with respect to the nitric acid used, in standardization and in analysis.

The Carbon or Ash Determinations in Graphite or Coke. By R. Helmhacker. *Eng. Min. J.*, **62**, 55. — The methods proposed include either the ignition of the coke or graphite in a platinum boat in a current of oxygen; or, for the determination of the ash, the ignition in a platinum crucible after the admixture of silver dust. The latter appears to promote the oxidation of the graphite and lessen the time required for combustion. The method is that proposed by Shtolba.

Determination of Sulphur in Coke and Coal. By R. Helmhacker. *Eng. Min. J.*, **62**, 106. — Shtolba's modification of Eschka's method is recommended, which involves the use of silver dust in place of magnesium oxide. A gram of the coal or coke is mixed with 1 gram of the silver powder, and one-half gram of sodium bicarbonate. The ignition requires but twenty to twenty-five minutes for a coal, or thirty to forty minutes for a coke. The subsequent procedure is the same as that laid down by Eschka.

Cyanide Copper Assay. By J. J. Beringer. *Eng. Min. J.*, **62**, 172. — The author defends the statements made in his *Text-Book on Assaying* regarding the effect of varying quantities of nitric acid upon the accuracy of the cyanide process, replying to the criticisms by F. N. Flynn. (Compare this *Rev.*, **2**, 69.)

Determination of Sulphur in Roasted Zinc Blend. By J. George Heid. *Eng. Min. J.*, **62**, 178. — The author points out that during the roasting of zinc ores the evolution of the sulphide sulphur is not complete, but that the roasted mass contains some sulphide, and also sulphate of magnesium and calcium formed during the calcination. To determine the sulphur present as sulphide the mass is twice treated with a 5 per cent. solution of sodium acetate, which removes the sulphur present as sulphates, after which the sulphides are treated with aqua regia in the usual manner.

The Determination of Sulphur in Roasted Zinc Ores. By P. A. MacKay. *Eng. Min. J.*, **62**, 291.—The communication states that, beside the sulphates of calcium and magnesium, sulphate of zinc is also formed during the roasting. The zinc present as sulphate may be determined by extraction with water, acidification with hydrochloric acid, and titration with potassium ferrocyanide, after the addition of ammonium chloride.

An Iodometric Method for the Determination of Phosphorus in Iron. By Charlotte Fairbanks. *Am. J. Sci.*, **152**, 181–185.—The method involves the application of the principles laid down in a paper on the determination of molybdic acid by iodine, (*this Rev.*, **2**, 68) to the determination of phosphorus through the estimation of the molybdic acid in the phosphomolybdate. The yellow precipitate is thrown down according to the directions prescribed by Blair and Whitfield (*Tech. Quart.*, **8**, 398), filtered on a Gooch filter, washed with 10 per cent. nitric acid, and finally with a 1 per cent. solution of potassium nitrate. After solution in ammonia (5 cc.), an excess of hydrochloric acid is added, and the determination of the molybdic acid is completed as described in the earlier paper. The ratio of P : MoO_3 is assumed to be 1.794. The results of analyses presented show a satisfactory degree of accuracy.

On the Reduction of Vanadic Acid by Hydriodic and Hydrobromic Acids, and the Volumetric Estimation of the Same by Titration in Alkaline Solution with Iodine. By Philip E. Browning. *Am. J. Sci.*, **152**, 185–188.—The author proposes a modification of the methods of Holverscheit (*Dissertation, Berlin*, **1890**) and Friedheim (*Ber.*, **28**, 2067), in the first of which the vanadic acid is reduced by boiling with potassium bromide and strong hydrochloric acid, and in the second by sulphuric acid and potassium iodide, the liberated iodine being absorbed and determined in both methods. The proposed modification involves the reoxidation of the vanadium in alkaline (bicarbonate) solution by iodine, and the titration for the excess of the iodine with arsenious acid. The solution of the vanadate is mixed with about 1 gram of potassium iodide and 10 cc. of sulphuric acid (1 : 1). The mixture is boiled until no more iodine is evolved, usually reducing it to a volume of about 35 cc. The flask is then cooled, the acid partially neutralized with potassium or sodium hydroxide, and finally with sodium bicarbonate. Tartaric acid is added in small quantity to avoid precipitation of vanadium tetroxide. Iodine is then added in distinct excess, and the solution put in a stoppered flask and set away out of sunlight for a half hour. The excess of iodine is then determined by arsenious acid. The vanadium is oxidized by the iodine from the tetroxide to the pentoxide. Accurate results were obtained by this method, as well as when potassium bromide was substituted for the iodide, but the distillation should continue in the latter case until the volume is reduced to 25 cc. to insure complete removal of the bromine.

Methods for the Analysis of Ores, Pig Iron, and Steel in Use in the Laboratory of the Ohio Steel Company, Youngstown, Ohio. By J. E. Bartlett. *Proc. Eng. Soc. W. Pa.*, **12**, *No.* 7 *Supplement.*—This paper is one of a series previously noted in *this Rev.* **2**, 18, and presents the methods in practical use in the laboratory above named. No brief review of the paper is practicable.

Proximate Analysis.

E. H. RICHARDS, REVIEWER.

A Comparison of the Babcock Test and the Gravimetric Method of Estimating Fat in Skim Milk. BY E. H. FARRINGTON. *Univ. Wis. Agr. Expt. Sta., Bull. No.* **52**, 1–8. — Diagrams showing the surface and side view of the fat globules in the neck of an ordinary test bottle indicates the causes of error in the usual method. To avoid these the author uses, in the one case, twice the quantity of milk in a bottle, the neck of which is somewhat smaller than the ordinary size, and in the other, a bottle of the usual size, but having two necks, one for filling and emptying, and the other very narrow, graduated to show .05 per cent. fat.

The Alkaline Tablet Test of Acidity in Milk and Cream. *Univ. Wis. Agr. Expt. Sta., Bull. No.* **52**, 8–16. — This ready means of controlling the quality of the many lots of milk received at a large dairy was first described in *Ill. Expt. Sta., Bull. No.* **32**, Its use is extending in the direction of the detection of preservatives added to retard acidification. For Pasteurizing, the acidity of milk and cream is limited to 0.2 per cent. The tablets may also be used to test cream before churning.

G. W. ROLFE, REVIEWER.

On the Estimation of Starch. BY THOMAS MCFARLANE. *Trans. Royal Soc. Can.*, 1, 19–23. — This paper describes a rapid scheme of proximate estimations, not only of starch, but also of gums, oil, sugar, etc., by successive treatments with appropriate solvents. All the constituents, except proteids, ash, and fiber, are determined from the loss of weight of the sample after treatment with the proper solvent. The general scheme is that usually employed, the novelty in the method consisting in the use of tubes filled with crysotile fiber for holding the sample. Starch is removed by immersing the tubes for an hour in water at 85° C., and then for several hours in a filtered malt infusion at 18° to 27°, and by washing till the filtrate no longer reacts with iodine. The author gives many data taken from his own work and that of others to show the reliability of the method.

The Determination of Reducing Sugars in Terms of Cupric Oxide. BY GEORGE DEFREN. *J. Am. Chem. Soc.*, 18, 749–766. — The author has made an elaborate investigation of O'Sullivan's modified Fehling process as applied to dextrose, maltose, and lactose, and has established laws affecting the influence of the concentration of the reducing sugars on the precipitation of the copper. From these data tables have been constructed giving the sugar corresponding to the copper oxide obtained. These tables are analogous to those of Allihn and Wein, and cannot but prove of practical value, as the method, while equally exact, is more rapid than that of Allihn. For the filtration the author uses a porcelain Gooch crucible, with an asbestos layer 1 cm. thick.

On the Inversion of Sugar by Salts. BY J. H. LONG. *J. Am. Chem. Soc.*, 18, 693–717. — In this second paper on the subject the author gives the detail of his method and publishes extensive data on the inversion of cane sugar by the following salts: Potassium alum, ferrous sul-

phate, zinc sulphate, cadmium chloride, manganous sulphate, manganous chloride, lead nitrate, ferrous chloride, ferrous bromide, and ferrous iodide. The inversions were made at 85°, the sugar concentration being 50 grams in 250 cc. Wide variations in the constancy of the inversion coefficients were found: of the salts experimented on potash alum alone gave a constant coefficient. The author notes that the accuracy of the inversion data of the heavy metallic salts is doubtless somewhat impaired by oxidation of the invert sugars as well as by the presence of levulose salts.

Photo-crystallization. By Ferdinand G. Wiechmann. *School Mines Quart.*, 17, 342–356. — By this term the author designates the action of light in influencing crystallization. 80 per cent. solutions of sucrose were partially inverted by hydrochloric acid and exposed to varying conditions of light for many days. A crystalline solid was formed and the percentage of invert sugar increased. By the author's own method of determining dextrose, levulose, and sucrose, which is given in detail, he finds that the speed of photo-crystallization is proportional to the intensity of light and the amount of invert sugar present. The crystals were in the main pure invert sugar, for which he suggests the name "invertose." He believes that the residual sucrose also forms compounds with the invert sugar which may be likened to alloys. Many analytical data are given.

A Study of Methods for the Determination of Starch. By H. C. Sherman. *School Mines Quart.*, 17, 356–365. — The author has experimented with all the more common methods. With grains and mill by-products he gets the usual discordant results by the acid methods, due to the well-known interference of the pentoses, which he demonstrates by qualitative tests. His conclusions are that the diastase or malt method is satisfactory, and the same is true in the main of Mærcker's method and of the author's modification of the salicylic acid method, which is given in detail. Pentoses should be tested for in the final solution. The article is valuable as reviewing the main features of the more common methods, as well as giving quite a complete bibliography of the subject.

Note on Sugar Analysis. By P. A. Levene. *School Mines Quart.*, 17, 470–471. — In gravimetric Fehling determinations the author estimates copper as follows: The suboxide, collected in a Gooch crucible, is dissolved in nitric acid nearly neutralized with sodium carbonate, 5 cc. of ammonia added, and the copper determined volumetrically by standard sulphocyanate solution or by the "hypo method." Analytical data are given to show that the method, for which the author claims priority, is reliable.

An Analytical Investigation of the Hydrolysis of Starch by Acids. By George W. Rolfe and George Defren. *J. Am. Chem. Soc.*, 18, 869–900; *Tech. Quart.*, 10. Many analytical data are given in this paper as evidence that in any homogeneous acid-converted starch product the specific rotary power bears a constant ratio to the cupric reducing power. Calculations of the three constituents, maltose, dextrose, and dextrin, from these data by the usual formulæ, in which the optical and reducing constants are based on the uniform approximate specific gravity factor .00386, when plotted give curves of remarkable regularity, which the authors believe confirm, in a striking degree, the generally accepted theories as to the formation of the three constituents and the persistence of their chem-

ical individuality through all the successive stages of hydrolysis. A table is added, calculated from these results, which gives the chemical constitution of a normally hydrolyzed starch solution, at stages of hydrolysis represented by each degree of rotation from starch paste to dextrose. The application of this table to the analysis of commercial glucose is explained. A digression of four pages is made to describe a simple commercial method of obtaining specific rotary powers. The rest of the paper is devoted to calculations of the speed of hydrolysis of starch solutions, to which are added a number of plates, showing a graphical expression of the results. Irregularities in the data from the higher converted solutions point to the presence of a possible decomposition-product, as noted by other observers, but the authors do not consider their results complete enough to warrant a conclusion on this point. The authors have been peculiarly unfortunate in their compilation, as there are not only many typographical errors, but also errors of calculation. While none of these affect the general results of the paper, they will, nevertheless, make necessary a recalculation of some of the tables.

F. H. THORP, REVIEWER.

The Analysis of Oakwood Extract by the Hide Powder Method. BY FRANZ CERYCH. *Leather Manufacturer*, 6, 40. — The author considers the hide powder method to be the most satisfactory process of tannin determination, since it shows just what the hides take up in the tan pits. He considers the divergent results obtained in different laboratories to be due to the quality of the powder and to improper filtering. He mixes 100 grams of hide powder with 35 grams of filter paper which has been made into a pulp with water, presses the mixture, and dries it in a cool place. The mass is then powdered and further dried over sulphuric acid. This leaves about 1.5 per cent. of moisture in the powder. Nine grams are taken for each analysis. A table of comparative results on the same extract is given, showing that hide powder with the admixture of filter paper gives results different from those obtained when the powder alone is used. He asserts that some of the hide powder is dissolved when no paper is added. Other sources of error are the variations of temperature and the use of solutions of tannin material varying in concentration.

S. P. PRESCOTT, REVIEWER.

Identification and Separation of the Principal Acids Contained in Plants. BY L. LINDOT. *Am. J. Pharm.*, 68, 439–441. — The process here proposed is based upon the solubilities of the acid citrates, malates, tartrates, and oxalates of quinine and cinchonine, and appears to be particularly applicable to isolation of citric and malic acids.

Quantitative Estimation of Carvone in Volatile Oils. BY EDWARD KREMERS AND O. L. SCHREINER. *Pharm. Rev.*, 14, 76–80. — The authors, having occasion to separate the ketonic from the non-ketonic constituents of caraway oil by means of the carvoxime reaction were led to investigate the applicability of this reaction in assay work on volatile oils. They give a critical examination of the previously known methods, and develop a mode of applying the oxime reaction, of which they say, "It certainly meets the requirements of a thoroughly scientific process of assay, although the estimation is not absolutely perfect, yet the results are surprisingly good for such

complex mixtures as volatile oils." The paper is thorough, well arranged, gives many valuable references, and is of particular interest to those engaged in detecting adulterations, or upon proximate organic analysis.

Assaying.

H. O. HOFMAN, REVIEWER.

Assays of Copper and Copper Matte. *Trans. Am. Inst. Min. Eng.*, 25, 250–292, 1000–1010. — The object of this joint investigation, which was made in accordance with the plan suggested by A. R. Ledoux (*Trans. Am. Inst. Min. Eng.*, 24, 575–582, 872–878), was to arrive at a method for assaying silver and gold-bearing copper bars and mattes which will give uniformly accurate results. Over twenty public assayers and metallurgical establishments took part in the work. The methods used and the highest and lowest results obtained are given below:

SILVER AND GOLD ASSAYS.

Method.	MATTE.		COPPER BORINGS.	
	Ag.	Au.	Ag.	Au.
Direct scorification	122.88–135.88	2.09–2.41	147.40–164.05	0.32–0.42
Crucible method	123.6	2.26	....	....
Combined wet and scorification method,	123.03–130.68	1.85–2.40	148.50–161.40	0.21–0.501
Combined wet and crucible method . .	126.20	2.09	161.35	0.42

COPPER ASSAYS.

Method.	Matte.	Copper borings.
Electrolysis	54.50–55.17	97.04–97.50
Cyanide	50.55–54.80	97.98
Iodide	55.0	....
Not stated	54.52	97.52

The results in the case of the gold and silver values are expressed in ounces per ton; in the case of the copper in per cents. The variations are seen to be very large. For details of the methods and the discussions the reader is referred to the original paper.

Separation of Silver from Gold by Volatilization. BY J. W. RICHARDS. *J. Franklin Inst.*, 141, 447–451. — In the Plattner blowpipe silver assay, buttons ranging from 0.5 to 1.5 mgr. are obtained if 100 mgr. of ore are taken; the weights are found by measuring the buttons and multiplying the weights of spheres of the same diameters by 0.6346 if the buttons are pure silver, by 0.7506 if pure gold. With doré-silver buttons Plattner recommends

to part with nitric acid in the usual way, then to gather the gold and melt it, and then measure the resulting button. The author considers that this manner of procedure is likely to cause loss. He found that the separation could be satisfactorily made by volatilizing the silver. He uses a hard, dense piece of charcoal, and a gas flame not over 2 cm. high, places the tip of the blowpipe half way through the flame and blows, so as to obtain a sharp-pointed flame about 1 cm. long. The charcoal, with the button in a shallow cavity, is held at an angle of about 45°, and approached to within 1 or 2 mm. of the blue tip of the flame, which descends vertically upon it. The button is heated for about three minutes to a bright yellow heat (1,100 to 1,200° C.), and then examined to see if the original white color has changed to brass yellow; if not, the operation is repeated. The brass-colored button, retaining about 5 per cent. silver, is then exposed to a higher temperature for two minutes at a time, until it assumes a pure gold color, the button being finally exposed to a white heat (1,500° C.) for one minute at a time, when the white charcoal ash will show, near the assay, a faint coating of volatilized gold, which quickly becomes crimson. The button, which now is free from silver, is taken out, cupelled, and measured. If the ore contains so little gold that the button becomes smaller than ¼ mm. before it shows the gold color, a pure gold button which has been cupelled and measured is added and the volatilization of the silver completed. The results are accurate, but the operation requires some skill and practice.

The Assay of Silver Sulphides. By H. van F. Furman. *Trans. Am. Inst. Min. Eng.*, **25**, 245–249, 998–1000. — The author prepared some silver sulphide to use as a base for his experiments, and, determining the silver in it by the Vollhard method, found it to contain 19,693 ounces silver per ton. He then assayed it by a combined wet and dry method, and by the scorification and crucible methods. The combination method is as follows: Dissolve 0.05 assay ton in nitric acid (27° B.), boil until red fumes disappear, dilute to 300 cc., add 110 cc. normal salt solution (1 cc. = 10 mgrs. silver), and stir. When settled add a strong solution of lead acetate, and then 1 cc. strong sulphuric acid drop by drop, and settle over night. Filter, dry precipitate, burn filter in 2½-inch scorifier in muffle, mix residue with 8 grams litharge, give cover of 20 grams test lead and 0.5 gram borax glass, scorify, and cupel. The yield in the tests averaged 99.56 per cent. of the silver charged. In the scorification assay from 30 to 40 grams test lead and from 0.5 to 1.0 gram borax were used, further varying amounts of Sb_2O_4, As_2O_5, Cu, $BaSO_4$, FeS, and Zn were added in the different tests. The average yield in silver was 99.44 per cent. In the crucible, the charges consisted of litharge, sodium bicarbonate, borax glass, lead flux, and nails; the crucibles were Denver 10-gram crucibles; the fusions were made in the muffle, and lasted each about thirty minutes. To the regular charges were added varying amounts of SiO_2, Sb_2O_4, As_2O_5, Cu, $BaSO_4$, Fe_2O_3, Zn, and S. The average yield in silver was 98.22 per cent. Thus the combined method gave the best results; then followed the scorification, and lastly the crucible method. Mr. Arents (p. 998) objects to the use of nails, which are sure to cause loss; the author replies to the criticism.

Assay of Auriferous Ores and Gravels by Amalgamation and the Blowpipe. By R. W. Leonard. *Trans. Am. Inst. Min. Eng.*, **25**, 645–650. — The ordinary assay of free-milling gold ores is unsatisfactory, as the amount of ore taken, being necessarily small, does not, as a rule, represent

a true average; further, it gives all the gold present in the sample, while it is desirable to know how much of the gold can be extracted by quicksilver. The method proposed by the author is to furnish results equal to those of a mill test of several tons. He samples down a quantity of ore in the usual way until several pounds are obtained, and then crushes it to pass a sieve of the required fineness. He then weighs out from 10 to 100 assay tons, according to the richness of the ore, divides it up into lots of from 3 to 4 assay tons each, rubs it with quicksilver in a mortar until all free gold is amalgamated, pans off the quicksilver, to be used in the next test, and reserves the tailings. When the entire sample has been thus treated, he distills the amalgam and quicksilver in a small cast-iron retort, and, when finished, adds test lead, which melts and collects the gold to be cupelled. The tailings are panned down to recover the sulphurets; they are weighed and assayed. Experimental data showing the results obtained by the fire assay, by the amalgamation blowpipe assay, and by mill tests of 2,000 pounds, accompany the paper.

Organic Chemistry.

J. F. Norris, Reviewer.

On the Behavior of Certain Derivatives of Benzol Containing Halogens. By C. Loring Jackson and Sidney Calvert. *Am. Chem. J.*, 18, 298–312. — It has been shown by Jackson and other investigators that in substituted aromatic compounds the firmness with which halogen atoms are bound to the ring is diminished by the presence of nitro groups, two oxygen atoms (as in chloranil, bromanil), hydroxyl, and probably carboxyl. The object of the work described was to determine whether less negative groups would have the same effect, and, for this purpose, compounds containing halogens alone were used. Consequently, the radicals removed and those rendering a removal possible belong to the same class. Tribromiodbenzene, $I(1),Br_3(2,4,6)$ reacted with but two of a variety of reagents, sodium ethylate and sodium methylate. The former caused a partial substitution of hydrogen for iodine in the cold, the latter only to a limited extent when boiling. Unsymmetrical tetrabrombenzene, $Br_4(1,2,3,5)$, was converted, to a less extent, into symmetrical tribrombenzene by boiling sodium ethylate, while tribromchlorbenzene was unaffected. Symmetrical tetrabrombenzene was next studied, as in this substance only two of the bromine atoms are in the positions to the one to be removed (ortho and para) which had proved effective in the unsymmetrical compound. This did not affect the result, as it was partly converted by boiling sodium ethylate into unsymmetrical tribrombenzene. Symmetrical tribrombenzene was also acted upon under the same conditions, but the reaction-products were not studied. Tetrabromdinitrobenzene, $Br_4(1,3,5,6)$, $(NO_2)_2(2,4)$ was converted by a cold solution of sodium ethylate into tribromnitroresorcin diethyl ether. Fuming nitric acid reacted with unsymmetrical tribromiodbenzene, setting free iodine and forming tribromdinitrobenzene, $Br_3(1,3,5),(NO_2)_2(2,4)$.

Transformations of Parasulphaminebenzoic Acid under the Influence of Heat. By Ira Remsen and A. M. Muckenfuss. *Am. Chem. J.*, 18, 349–365. — When parasulphaminebenzoic acid is heated at 285° for three hours, it is transformed into a substance which when dissolved in water is in turn transformed into acid ammonium parasulphobenzoate. From the facts

that there is no loss in weight caused by the heating, that the product is very soluble in water, and that, as has been shown by the authors (*Am. Chem. J.*, **18**, 150; *this Rev.*, **9**, 10), the nitrogen in the sulphamide easily passes to the carbon atom of the carboxyl group, it appears not improbable that the effect of heat is to cause the following change:

$$C_6H_4\begin{cases}COOH\\SO_2NH_2\end{cases} \longrightarrow C_6H_4\begin{cases}CONH_2\\SO_2OH\end{cases}.$$

The benzaminesulphonic acid would take up water and yield acid ammonium parasulphobenzoate. Parasulphaminebenzoic acid when heated at 220° for eight hours yielded an infusible substance slightly soluble in boiling water, neutral toward litmus, insoluble in alkaline carbonates and in cold and hot alcohol. It gave off two molecules of ammonia when boiled with sodium hydroxide. A solution in concentrated sulphuric acid was heated to 200° without decomposition. Analysis showed it to be isomeric with the diamide of parasulphobenzoic acid. It is accordingly called the infusible diamide. Concentrated hydrochloric acid at 200° decomposed it into acid ammonium parasulphobenzoate and ammonium chloride. Attempts to liberate one half of the nitrogen as ammonia were unsuccessful. The diamide of parasulphobenzoic was prepared from the acid in the usual way, and differed in properties from the infusible diamide. It loses one half of its nitrogen when boiled with an alkali, and is transformed into parasulphaminebenzoic acid. It was found impossible to change one diamide into the other. In the filtrate obtained in the preparation of the infusible diamide was found an acid isomeric with parasulphaminebenzoic acid. Several of its salts were made, but only the ammonium and barium compounds are well characterized. The former crystallizes in short, stout, transparent prisms, quite different from the aggregates of needles formed by ammonium parasulphaminebenzoate. As the acid gives up its nitrogen with difficulty, it is improbable that it is benzaminesulphonic acid, $C_6H_4\begin{cases}CONH_2\\SO_2OH\end{cases}$. Further work is necessary before constitutional formulæ can be assigned to the compounds.

On Benzimidoethyl and Benzimidomethyl Ethers. By F. W. Bushong. *Am. Chem. J.*, **18**, 490–491. — Contrary to previous statements, the author finds that benzimidoethyl and benzimidomethyl ethers are stable bodies, which can be distilled without decomposition. By passing dry hydrochloric acid into benzonitrile and alcohol a crystalline addition-product was obtained, which, after drying, was cautiously added to a 10 per cent. solution of sodium hydroxide. The resulting oil was extracted with ether and after fractionation at 10 to 15 mm. yielded a pure product. The methyl compound boiled at 96° at 10 mm. and at 206° at ordinary pressure. The boiling point of the ethyl compound was 106°–109° at 15 mm. and 218° at ordinary pressure.

Dianthranol. A Dihydroxyl Derivative of Dianthracene. By W. R. Orndorff and C. L. Bliss. *Am. Chem. J.*, **18**, 453–465. — Orndorff and Cameron have shown (*Am. Chem. J.*, **17**, 517) that anthracene when dissolved in benzene is changed by the action of sunlight into dianthracene, a polymer having twice the molecular weight of anthracene. The authors find that a similar change takes place with anthranol. Dianthranol was also formed by boiling anthranol in xylene for twelve hours, in the presence of air (in an atmosphere of carbon dioxide the change does not take

place), and by shaking anthranol in potassium hydroxide with air. When prepared by either of these methods there is always a partial oxidation to anthraquinone. The pure product, after crystallization from glacial acetic acid and from benzene, consists of colorless tabular crystals, which melt with decomposition at about 250° with formation of some anthranol. It is almost insoluble in ether, slightly soluble in alcohol, more soluble in acetone, glacial acetic acid, and benzene. Dianthranol can be separated from anthranol, as the former is insoluble in alkalies. A complete crystallographic study of anthranol and dianthranol was made. The former crystallizes in the orthorhombic system, the latter in the monoclinic. The diacetyl derivative was formed by heating the compound with a large excess of acetic anhydride and sodium acetate in a sealed tube at 180°–190°. It crystallizes from dilute alcohol in light yellow plates melting at 276°–279°. A constitution formula for dianthranol is proposed analogous to that offered for dianthracene (*loc. cit.*).

On the Halogen Derivatives of the Sulphonamides. By J. H. Kastle, B. C. Keiser, and Earnest Bradley. *Am. Chem. J.*, **18**, 491–501. — Benzenedichlorsulphonamide, $C_6H_5SO_2NCl_2$, was prepared by leading into a solution of benzenesulphonamide in the smallest quantity of sodium hydroxide (1–10) a rapid current of chlorine. The white crystalline precepitate was washed with hot water, dissolved in alcohol, and precipitated with water. The compound crystallizes in pearly white laminæ, which melt at 70° and explode when heated rapidly to 220°. At 150° chlorine is evolved, and benzenesulphonchloride is formed. Similar chlorine compounds were prepared from toluenesulphonamide and *p*-brombenzenesulphonamide, which melt at 80° and 106°, respectively. Benzenedibromsulphonamide, melting point 110°, was prepared in the same way. With iodine, compounds, perhaps of the nature of periodides, were obtained and will be described later. The authors put forward the following as evidence that the compounds are substitution- and not addition-products: (1) When heated they explode with evolution of halogen, whereas, if the structure were $C_6H_5SO_2NH_2Cl_2$, it is probable that hydrochloric acid would be formed. When heated slowly to 170° the decomposition is expressed by the equation $C_6H_5SO_2NCl_2 = C_6H_5SO_2Cl + N + Cl$. The small amount of hydrochloric acid which is formed is probably due to the action of the chlorine on the phenyl group. (2) The action of strong acids is best explained by the equation $C_6H_5SO_2NCl_2 + 2HCl = 4Cl + C_6H_5SO_2NH_2$. This reaction is analogous to that between nitrogen trichloride and hydrochloric acid. (3) The compounds are good oxidizing agents, furnishing two atoms of oxygen, whereas an addition-product would give but one atom. This reaction was tested with sulphurous acid, hydriodic acid, and sodium arsenite.

Bromine Derivatives of Metaphenylene Diamine. By C. Loring Jackson and Sidney Calvert. *Am. Chem. J.*, **18**, 465–490. — Tribrommetaphenylene diamine is prepared by passing a stream of air and bromine into a solution of metaphenylene diamine. As an excess of bromine destroys the compound, the precipitate is frequently filtered off as the reaction proceeds. The compound crystallizes from alcohol in long slender needles, melts at 158°, is freely soluble in hot alcohol, ether, benzene, chloroform, glacial acetic acid, and carbon disulphide, slightly soluble in ligroïn, and insoluble in water. Its hydrochloride was prepared by saturating a solution of the base in benzene with hydrochloric acid gas. The diacetamide $C_6HBr_3(NHC_2H_3O)_2$

crystallizes from acetic acid in small white plates, does not melt at 330°, and is slightly soluble in common solvents. Tribromphenylenediurethane, $C_6HBr_3(NHCOOC_2H_5)_2$, was prepared by treating the diamine with chlorcarbonic ester for three hours. It crystallizes best from a mixture of alcohol and water, and melts at 212°. The tribromdinitrobenzene, melting point 192°, made from symmetrical tribrombenzene, when reduced with zinc and acetic acid gave tribromphenylene diamine, whereas tin and hydrochloric acid removed the bromine atoms forming metaphenylene diamine. The bromine atoms were also removed from tribromphenylene diamine when treated with tin and hydrochloric acid. By the same treatment symmetrical tribrombenzene was not affected, and the bromine atom ortho to the amido group in symmetrical tribromaniline was removed. Metaphenylene diacetamide yielded, on bromination, a dibrom-derivative, which crystallized from hot glacial acetic acid and melted at 259°–260°. From this compound dibrommetaphenylene diamine was prepared by the action of hydrochloric acid. Its hydrochloride and hydrobromide are described. Monobrommetaphenylene diamine was obtained by the reduction of tetrabromdinitrobenzene with tin and hydrochloric acid. It melts at 93°–94°, and is readily soluble in acetone, alcohol, ether, or chloroform. The compound is strongly basic, forming salts soluble in water. When brominated in ethereal solution tetrabrommetaphenylene diamine is formed. It crystallizes from a mixture of chloroform and ligroïn in white needles, which melt at 212°–213°.

On Some Mercury Salts of the Anilides. By H. L. Wheeler and B. W. McFarland. *Am. Chem. J.*, 18, 540–547. — Mercury salts of formanilide and paraformtoluide have been prepared, and these, as well as mercury acetanilide, react with benzoyl chloride, bromine, and iodine as if they had the metal joined to nitrogen. The reaction between mercury formanilide and benzoyl chloride is typical:

$$(C_6H_5NCHO)_2Hg + C_6H_5COCl = C_6H_5N\begin{cases}CHO\\HgCl\end{cases} + C_6H_5N\begin{cases}CHO\\COC_6H_5\end{cases}.$$

The mercuric halogen compound is similar in structure to the well-known compounds $H_2N - HgCl$ and $C_6H_5N\begin{cases}H\\HgCl\end{cases}$. As the diacid anilide formed, when treated with dilute acid or alkali, is decomposed into benzanilide and formic acid, it follows that it has both acid groups attached to nitrogen. If the anilide were an oxygen derivative, $C_6H_5N = C\begin{cases}H\\O.COC_6H_5\end{cases}$, the formyl group could not be removed without also removing the benzoyl radical, and the decomposition-products would be aniline, formic acid, and benzoic acid. Mercury formanilide, $(C_6H_5NCHO)_2Hg$, is prepared by dissolving formanilide and mercuric bromide in alcohol, adding the calculated quantity of sodium ethylate, and diluting with water. The resulting precipitate crystallizes from water in colorless needles, which melt at about 194°. When mercury formanilide is suspended in benzene and one molecule of benzoyl chloride is added, reaction takes place. On filtering and washing the residue pure chlormercury formanilide, $C_6H_5N\begin{cases}CHO\\HgCl\end{cases}$, remains, plates melting at 191°. On concentrating the benzene solution, formylbenzanilide, $C_6H_5N\begin{cases}CHO\\COC_6H_5\end{cases}$, is obtained in colorless brittle prisms, melting point 112°. Brommercury formanilide, $C_6H_5N\begin{cases}CHO\\HgBr\end{cases}$, was obtained when formanilide was suspended in carbon bi-

sulphide and one molecular proportion of bromine added. Iodmercury formanilide was prepared in the same way. By using alcohol as solvent and mercuric acetate, mercury formanilide acetate, $C_6H_5N\begin{cases}CHO\\HgOCOCH_3\end{cases}$, was obtained in colorless prisms. Analogous compounds derived from formparatoluide were formed. Acetbenzanilide, $C_6H_5N\begin{cases}COCH_3\\COC_6H_5\end{cases}$, crystallizes from dilute alcohol in long needles, which melt at 68°.

The Separation of Trimethylamine from Ammonia. By HERMANN FLECK. *J. Am. Chem. Soc.*, 18, 670–672. — The author shows that the methods for the separation of the two bases now in use are not quantitative. Exact results are obtained as follows: The mixed chlorides are repeatedly extracted with portions of a total of five or six times the volume of boiling absolute alcohol and the solvent distilled off. An excess of sodium hydroxide is added, and the gases formed on boiling passed into a large quantity of water. After the liquid is exactly neutralized with sulphuric acid, it is evaporated to dryness and the residue extracted with a large volume of cold absolute alcohol, which dissolves the trimethylamine sulphate. That the extraction was complete was evident from the absence of the fishy odor when the extracted residue was treated with an alkali. The extracted matter was shown to be pure by an analysis of the platinum double salt made from it.

Aluminum Alcoholates. By H. W. HILLYER. *Am. Chem. J.*, 18, 621–622. — Amalgamated aluminum, prepared by the method of Wislicenus and Kaufmann (*Ber.*, 28, 1323), reacts with absolute alcohol in which mercuric chloride or fuming stannic chloride is dissolved. Hydrogen is evolved, much heat is developed, and the action continues until, on cooling, the whole gelatinizes. When stannic chloride is used the resulting compound, distilled under diminished pressure, furnished a distillate free from tin and rich in aluminum. An analysis seemed to indicate that the substance had the composition $Al(OC_2H_5)_2OH$. Two experiments with methyl alcohol gave good evolution of gas, but no substance was formed which could be distilled. With normal propyl alcohol, aluminum tripropylate was obtained. Isopropyl and amyl alcohols react with aluminum in the presence of aluminum chloride and spongy tin. The work is being continued.

Phthalimid. By J. A. MATHEWS. *J. Am. Chem. Soc.*, 18, 679–682. — Phthalic acid, propionitrile, and three drops of acetic anhydride were heated in sealed tubes for various lengths of time at different temperatures. In each case phthalimid was obtained. The yield was 92.5 per cent. when equal molecules were heated for five and one half hours at 180°–200°. After washing the resulting mass with dilute potassium carbonate and crystallizing from alcohol, the product melted at 229.5°. It was shown to be phthalimid by its reactions with potassium hydroxide and with ammonia. It was dissolved by the former with evolution of ammonia. The latter converted it into phthalamid.

On the Use of Antimony Trichloride in the Synthesis of Aromatic Ketones. By WILLIAM J. COMSTOCK. *Am. Chem. J.*, 18, 547–552. — The author recommends antimony trichloride as a substitute for aluminum chloride in the preparation of aromatic ketones on account of its cheapness. The

reaction does not take place at the ordinary temperature, and cannot be successfully applied with low-boiling chlorides. The yields were about the same as when aluminum chloride is used. A 40 per cent. yield of pure methoxybenzophenone was obtained. 112 grams benzoyl chloride, 70 grams benzene, and 300 grams antimony trichloride gave a 74 per cent. yield of pure crystallized benzophenone. 56 grams benzoyl chloride, 40 grams toluene, and 60 grams antimony trichloride gave a mixture of the ortho and para ketones 80 per cent. of the theoretical. 64 per cent. of this mixture was the para ketone, whereas with aluminum chloride 80 to 95 per cent. is obtained. 28 grams benzoyl chloride, 22 grams paraxylene, and 20 grams antimony trichloride gave an 80 per cent. yield. The use of antimony chloride with chloroform, benzyl chloride, and benzal chloride is not recommended.

Halogen Derivatives of Thymol and Carvacrol. By Leo C. Urban. *Pharm. Rev.*, 14, 58. — Carvacrol iodide was prepared by adding slowly to a solution of 2 grams of carvacrol in 40 cc. sodium hydroxide (1–10) an aqueous solution of iodine in potassium iodide. The product was a bulky, grayish-yellow, amorphous powder having a faint aromatic odor, soluble in ether, chloroform, benzin, and the fixed oils. It combines the antiseptic properties of carvacrol with those of iodine. Thymol and carvacrol bromides were prepared in the same manner.

Notes on Bismuth Subgallate and Substannate. By Fred. A. Sieker. *Pharm. Rev.*, 14, 85. — Improved methods of preparation of the above substances of interest to pharmacists are described.

The Constitution of the Acid Amides. By Arthur Lachman. *Am. Chem. J.*, 18, 600–608. — A brief summary of the work that has been done on the amides shows that the question is in an unsettled state, and that what evidence there is points to a division of the amides into two groups; one containing oxamethane, the various carbamides, benzenesulphonamide, having the customary amide formula; the other embracing acetamide, benzamide, and some of their substitution-products, having the imidohydroxy structure. In order to test this classification, the oxygen and nitrogen atoms, and the double bond that exists in the second group, of various amides, were subjected to examination by the following reagents: Phosphorus trichloride, hydroxylamine, alcoholic hydrochloric acid, nitrous acid, ethyl iodide, hydrocyanic acid, and ethyl hypochlorite. Negative results were obtained except with phosphorus trichloride. Benzamide was transformed into benzonitrile, whereas oxamethane was not affected. The action with the former compound was not one of dehydration, as oxamethane readily loses water and passes into the nitrile. Oxamethane has been shown to form an amide chloride, and this amide formula explains its indifference to the trichloride. Benzamide reacts in the same manner with both chlorides of phosphorus, forms as first product, not an amide, but an imide chloride, and therefore contains a hydroxyl group.

A Review of Recent Synthetic Work in the Class of Carbohydrates. By Helen Abbott Michael. *J. Franklin Inst.*, 142, 217–240. — A lecture delivered before the Franklin Institute, in which the author gives a brief account of the work in the sugar group.

Inorganic Chemistry.

H. Fay, Reviewer.

On the Existence of Selenium Monoxide. By A. W. Pierce. *Am. J. Sci.*, **152**, 163–167. — Chabrié, working with certain organic compounds which had been previously oxidized with nitric acid, obtained selenium from them by reducing with sodium sulphite and hydrochloric acid. He found that in heating the selenium thus prepared there was no gain in weight at 100° C., but at 180° C. there was enough increase in weight as to suggest the formation of the monoxide. The author, using selenium prepared from the dioxide by reducing with sulphurous acid or potassium iodide, heated separate portions, previously dried to constant weight at 100° C., at various temperatures from 110° C. to 180° C. during varying intervals of time, and found in all cases a loss in weight. A weighed amount of selenium heated to 180° C., in a tube through which air was drawn, was found to lose weight, and a mirror of red elementary selenium was formed on the cooler portion of the tube. Another experiment was made in which the volatilized selenium was collected, and the total weight of selenium was found to be the same. By heating selenium dioxide and selenium together no evidence of the formation of a gaseous product was obtained, nor, indeed, any evidence of chemical action.

Zirconium Tetraiodide. By L. M. Dennis and A. E. Spencer. *J. Am. Chem. Soc.*, **18**, 673–679. — The authors first attempted to prepare zirconium tetraiodide by passing the vapor of iodine over zirconium. The metal prepared by the method of Winkler, who reduced zirconium dioxide by magnesium, consists principally of the monoxide, and when iodine vapor was passed over the heated oxide no evidence was obtained of the formation of zirconium tetraiodide. Negative results were also obtained when pure zirconium, made by reducing potassium fluozirconate with metallic sodium, was heated in a current of hydrogen with iodine vapor. The next method tried was to heat pure zirconium in a current of hydriodic acid. The hydriodic acid was formed by bringing the vapor of iodine and hydrogen together in a tube containing pumice, the rear portion being heated, and the front being cooled and filled with cotton to collect the excess of iodine. This tube was directly connected with another tube resting in a combustion furnace. On heating the zirconium in hydriodic acid there was at first formed a sublimate which collected in the cooler end of the tube, and proved to contain mostly iron and iodine. When the tube was heated to bright redness a white crystalline sublimate of zirconium tetraiodide was formed. This substance is insoluble in water, in nitric and hydrochloric acids, in aqua regia, and in carbon bisulphide. For analysis it was decomposed and dissolved by sulphuric acid, together with nitric and nitrous acids. The solution was diluted with water and the zirconium precipitated with ammonia. The iodine was obtained by fusing the substance in a mixture of sodium and potassium carbonates, dissolving in water, and precipitating with silver nitrate. — Under the microscope the crystals of zirconium tetraiodide are clear, colorless cubes. Heated in hydrogen it becomes black, and iodine and hydriodic acid are formed. Heated in the air the substance melts and sublimes.

A Method for Obtaining Crystalline Silicon. By G. de Chalmot. *Am. Chem. J.*, **18**, 536–540. — In a previous paper the author described the preparation of calcium silicide by heating together in an electric furnace sil-

ica, calcium oxide, and carbon. He now finds that metallic silicon can be obtained by dissolving out the calcium silicide with hydrochloric acid and the free silicic acid with hydrofluoric acid. Silicon obtained by this method contains as low as 1 per cent. of iron. Using pure materials, a very small yield of calcium silicide was obtained, and it was found necessary for its formation to have some iron present. Replacing calcium oxide with other oxides, larger yields of silicide were obtained. With the oxide of manganese, Mn_3O_4, a crystalline alloy was obtained consisting principally of manganese silicide and crystalline silicon. By dissolving the manganese silicide in cold hydrofluoric acid a crystalline powder free from manganese is left. 97.77 per cent. of this residue is pure silicon. To determine the composition of the manganese silicide the substance was decomposed by cold hydrofluoric acid and the residual silicon weighed. Knowing the percentage of iron and calcium, and supposing them to exist in the form of $FeSi_2$ and $CaSi_2$, the manganese silicide was calculated to have the formula $MnSi_2$. This silicide differs from the one described by Vigoureux in not being easily attacked by dilute acids.

The Action of Metals on Nitric Acid. By George O. Higley and W. E. Davis. *Am. Chem. J.*, 18, 587–590. — Nitric acid has been previously shown to act on lead and copper, giving the same products, viz., nitrogen dioxide, trioxide, nitric and nitrous oxides. Using silver and nitric acid of various degrees of dilution, neither nitrogen nor nitrous acid are formed. The principal reduction-product with concentrated acid is nitrogen dioxide, but with acids of greater dilution there is a rapid and somewhat regular decrease of this gas, due to a greater tendency to decomposition with water into nitric oxide and nitric acid. When dissolved in dilute nitric acid no nitrous oxide is formed. Silver appears to be less reactive than copper.

Oxidation of Sodium Sulphide and Hydrosulphide to the Sulphate by Electrolysis. By Frank W. Durkee. *Am. Chem. J.*, 18, 525–536. — To show whether the ammonium compounds in gas liquors could be oxidized by an electric current into ammonium sulphate, experiments were made on solutions of ammonium sulphide and hydrosulphide. Using carbon or copper electrodes, a 3-ampere current produced no sulphate, but with platinum electrodes considerable sulphate was produced. To determine whether the oxidation was complete a solution of sodium sulphide was electrolyzed with a 3.1-ampere current for eleven hours, and, after filtering from separated sulphur, an aliquot part of the filtrate was evaporated in a weighed platinum crucible and the sodium sulphate found calculated to sodium. Having used .0859 gram sodium in two experiments, .0857 and .0854 gram were obtained. — A solution of sodium hydrosulphide, made from a standardized solution of sodium hydroxide, electrolyzed for eleven hours with a 3-ampere current, gave results indicating complete oxidation. As soon as the current is passed through the solution, hydrogen escapes from the negative electrode, but very little oxygen at the positive. After the current had passed a short time, the solution became yellow about the negative electrode, and soon after light yellow sulphur made its appearance at the positive electrode. It scaled off during the process, and a greater part of it dissolved. Later fine white sulphur separated about the positive electrode, but dissolved as it sank through the liquid; subsequently with the disappearance of the yellow color of the solution the sulphur remained undissolved. At this stage of the electrolysis more oxygen escaped than at any other time. Sulphuric acid was also

formed in solution. These phenomena are interpreted by the author as being due at first to the formation of polysulphides, giving the yellow color, with deposition of yellow sulphur, and next, to the formation of thiosulphate and separation of white sulphur. To prove this supposition five different solutions of sodium sulphide, containing the same amount of sodium in each, were subjected to a 3-ampere current for different periods of time, varying from one hour and thirty minutes to six hours and forty minutes, and the sodium determined in each of the compounds present at any one time. The sodium as sulphate was determined by means of barium chloride in hydrochloric acid solution; as sulphide, by means of standard ammoniacal zinc chloride solution, using nickel nitrate as indicator; as thiosulphate, by first removing the sulphide and separated sulphur by zinc chloride, oxidizing with bromine, and precipitating with barium chloride. Knowing already the weight of sodium as sulphate, that portion existing as sodium thiosulphate can be calculated. Free hydroxide was determined by standard sulphuric acid. The sodium as polysulphide was determined by adding an alkaline solution of zinc chloride, when all sulphur above one atom separates along with zinc sulphide. The whole was then oxidized to sulphuric acid and zinc sulphate. The total amount of sodium found agreed very closely with the amount put in, showing the different compounds to be present as supposed. This method of analysis shows that the sulphides disappear first, the hydroxide next, and finally the thiosulphate. — An alternating current gave similar results, but under the influence of the current considerable platinum was dissolved.

Chromic Hydroxide in Precipitation. By Harrison E. Patten. *Am. Chem. J.* **18**, 608–618. — Recoura has shown that chromium forms complex acids, bases, and salts, in which chromium, in combination with varying amounts of the radicle SO_4, acts as a complex radicle. The author has investigated the precipitation of chromium hydroxide, under definite conditions, to study the effect of adhesion and to see "whether the chromium or the sulphuric acid, or the combined action of the two, causes the disturbance, and whether there is a recombination of the elements to form a new compound, or merely a mechanical action." To determine whether or not sulphur trioxide, chlorine, or potassium oxide is carried down by chromium when precipitated by potassium hydroxide in presence of four molecules of potassium sulphate, solutions containing one molecule of chromium chloride, made by evaporation of a weighed amount of potassium bichromate with hydrochloric acid, were precipitated by six, five, four and one half, four, three and one half, three, and eight molecules of potassium hydroxide. Both the filtrate and the whole number of constituents were analyzed in aliquot portions. In only one case, when five molecules potassium hydroxide were used, was adhesion noticed. Here $3\frac{1}{10}$ per cent. of the total sulphur trioxide introduced was carried down in the precipitate, while the potassium oxide and chlorine were undisturbed. When no sulphate was present the precipitate, which was formed on adding three, four, or five molecules of potassium hydroxide would not settle, and, after standing, went into solution again. With six molecules of potassium hydroxide to one of chromium chloride there was a definite precipitate, which did not carry down any chlorine. In the first series with potassium sulphate present the fractional precipitation gave definite precipitates, filtering clear, and settling rapidly. To make sure that the precipitation was due to the sulphate, magnesium sulphate was added to a redissolved system containing five molecules potassium hydroxide to one of chromium chloride. There was immediate and

almost complete precipitation. No magnesium was carried down. Calcium, sodium, and ammonium sulphates were tried with similar results. Chlorides and nitrates do not precipitate chromium from this solution. — To investigate this action further, the amount of chromium chloride and potassium hydroxide was tripled, but the sulphate left the same as in the first series of precipitations. In all experiments using three, four, five, and six molecules potassium hydroxide, adhesion took place in each instance. In this last series it is shown that, if the adhesion is mechanical in its nature, the action should be proportional to the amount of precipitate present. Practically the same amount of sulphur trioxide is carried down when using three as when using six molecules of potassium hydroxide, while there is about seven times as much precipitate in the latter case. With five molecules there is over three times as much sulphur trioxide carried down as with six molecules. — The author considers that the sulphur trioxide must be united to the chromium, possibly to form a complex compound. In the first series of experiments no sulphur trioxide is carried down except when five molecules of potassium hydroxide are used. This is explained by assuming that a primary and secondary reaction takes place, combination of sulphur trioxide and chromium sesquioxide being effected, and then a breaking down of the compound by water.

The Reduction of Permanganic Acid by Manganese Superoxide. By H. N. Morse, A. J. Hopkins, and M. S. Walker. *Am. Chem. J.*, **18**, 401–419. — The authors have shown that the instability of potassium permanganate and permanganic acid is due to the presence of manganese dioxide, which reduces the solution with liberation of three fifths of the active oxygen of the permanganic acid. After the solution once begins to lose strength it declines with increasing rapidity, owing apparently to the increased quantity of oxide present. If a solution of potassium permanganate containing considerable oxide is heated to its boiling point, it loses color after a time. This change of color is found to be due to loss of three fifths of the total active oxygen, as shown by determining the strength of the solution before and after heating. The loss of oxygen was also determined by measuring the gas itself. A solution of equal concentration, which has been filtered through asbestos, is only slightly altered under the same conditions. Solutions of pure potassium permanganate, carefully filtered to remove suspended oxide, are quite stable whether kept in darkness or diffused light, but are decomposed in direct sunlight. The oxide resulting from the complete reduction of a neutral solution of potassium permanganate contains all of the potassium of the original salt, and is, therefore, neutral. — Precipitated manganese dioxide, formed by the slow decomposition of a neutral solution of potassium permanganate, or by addition of manganese sulphate to an acidified solution of potassium permanganate, has the ratio of oxygen to manganese, 2 : 1, only so long as there is present unreduced permanganate or permanganic acid. In the absence of either the oxide loses oxygen at the ordinary temperature, but the oxygen is restored in their presence.

Corrosion from Dissolved Copper. By Kirchhoff. *Iron Age*, **58**, 309. — The paper refers to a peculiar coating of copper on an iron pipe of a boiler used to furnish steam for several copper vacuum jackets. The condensed steam carried back some copper compound in solution which reacted with the iron oxide on the outside of the pipe depositing metallic copper.

Biological Chemistry.

Animal and Plant Chemistry.

S. C. Prescott, Reviewer.

Nitrogen Assimilation in the Cotton Plant. By C. E. Coates and W. R. Dodson. *J. Am. Chem. Soc.*, **18**, 425–428. — Experiments carried on by following Hellriegel's methods as far as possible gave entirely negative results. Great care was taken that the plants should receive no nitrogenous food. The plants used for the experiments died within a few weeks, apparently of nitrogen starvation. The authors conclude that under the conditions employed the cotton plant does not assimilate atmospheric nitrogen.

Further Notes upon the Fats Contained in the Tuberculosis Bacilli. — By E. A. de Schweinitz and M. Dorset. *J. Am. Chem. Soc.*, **18**, 449–451. — This is a continuation of the work previously reported. The fats obtained have been analyzed as completely as the small amounts obtained would allow. The principal fatty acid found was palmitic. A small quantity of another acid with a high melting point was found, probably arachidic acid. A very small amount of an acid melting at 42° to 43° C. was found. This was supposed to be lauric acid. The authors claim that several acids still remain to be identified, and are collecting material for this work.

The Effect of Acidity upon the Development of the Nitrifying Organisms. By E. E. Ewell and H. W. Wiley. *J. Am. Chem. Soc.*, **18**, 475–484. — After giving the history of the literature of the nitrifying organisms, and quoting results obtained by other workers, the authors give their own results obtained by inoculating an artificial medium with soils. After being allowed to develop some time, determinations were made of acidity and of the amount of nitrogen changed to nitrate. Forty-four tests were made. In five cases no nitrification took place; in the others nitrification occurred in amounts varying from 11 to 170 parts per million, the average for the series being 28 parts per million of nitrogen nitrified. Organisms from various parts of the country seem to be uniform in their ability to endure acidity, and the nitric and nitrous organisms have about equal powers in this respect. Nitrification ceases when the acidity exceeds 3 or 4 cc. normal alkali per liter.

Chemical Nature of Diastase. By Thomas B. Osborne and George F. Campbell. *J. Am. Chem. Soc.*, **18**, 536–542. — In this second paper on the subject abundant evidence of the evasive nature of diastase is given. Hundreds of trials to determine the effect of conditions were made with these probable results. The purer the diastase, the more sensitive is it to conditions. Testing by maltose-producing power may be no criterion of purity. The proteid is not the only factor in its amylolytic action, sodium chloride increasing, while citric acid inhibits its power. They regard it highly probable that the presence of albumin is essential, and that the enzyme is not a substance precipitated mechanically with the proteid.

The Proteids of Malt. By Thomas B. Osborne and George F. Campbell. *J. Am. Chem. Soc.*, **18**, 542–558. — Another valuable contribution, emphasizing the differences in composition between barley and malt. As in all

their papers, full details are given. The results show the presence of malt-globulin (*Bynedestin*), malt-albumin (*Leucosin*), apparently identical with that found in wheat, rye, and barley, but here always associated with a proteose, two protoproteoses, a deutero and a heteroproteose, two other proteids, one called *Bynin* and another whose composition and properties remain undetermined. In germination the proteids of barley undergo changes without or before becoming proteoses. Albumin appears unchanged in nature, but increased in quantity, while hordein and edestin are both replaced by proteids richer in carbon and poorer in nitrogen.

Proteids of the Potato, Legumin, and Other Proteids of the Pea and Vetch, Conglutin, and Vitellin. By Thomas B. Osborne and George F. Campbell. *J. Am. Chem. Soc.*, **18**, 575–623. — These three papers are notable for their clearness and fullness. Each step in the processes are so faithfully reported that their repetition is possible. Results from a vast amount of work are found here. The potato has for proteids a globulin, — *tuberin* — and a small amount of a proteose. — Legumin has been a familiar word for nearly a century. Here for the first time the existence of a definite substance to fit that name is demonstrated. — Peas and vetches have the same proteids, a globulin, — *legumin* — and small quantities of another proteid not fully examined. — These chemists have rendered great service by clearing up the confusion and uncertainty concerning conglutin and vitellin. The paper covers all the substances hitherto described as either, namely, six perfectly distinct proteids, whose relations are exhibited in a tabular view.

Chemistry of the Cactaceæ. By Ervin E. Ewell. *Am. J. Chem. Soc.*, **18**, 624–625. — This paper is "an historical *résumé* and preliminary note," opening a field for investigation of new alkaloids. Here one finds condensed into a remarkable table, most convenient for reference, all that is known about this group of alkaloids.

Bacteria in Milk Sugar. By A. R. Leeds. *J. Am. Chem. Soc.*, **18**, 687–688. — The author finds that bacteria are commonly present as an impurity in lactose, and that they produce lactic acid, but he has been unable to isolate *B. acidi lactici*. The bacteria found developed well on peptone gelatin. The maximum number found for 1 gram of lactose was 1,400.

Occurrence of Amines in the Juice of the Sugar Cane. By J. L. Beeson. *J. Am. Chem. Soc.*, **18**, 743–744. — It is pointed out in this article that amines are present in cane juice in small quantities, a fact never before known. An attempt was made to purify and determine the amines, but the quantity of product was so small that it is impossible to say whether it was composed of a single amine or a mixture of amines. The occurrence of amines in cane juice is a matter of great importance, and will, it is hoped, soon be further studied.

The Tannins of Some Ericaceæ. By Bertha L. DeGraffe. *Am. J. Pharm.*, **68**, 313–321. — The classification of tannins by Wagner (1866) into physiological and pathological has been unsatisfactory. Tannins from the following drugs were isolated and quite thoroughly examined: *Uva Ursi*, *Gaultheria*, *Chimaphila*, *Manzanita*, mountain laurel, and trailing arbutus. Methods of purification, tables of comparative reactions, and decomposition-products are given, and the conclusion is that either kind of tannin may be physiological.

On the Identification of Morphine in Toxicological Cases. By J. B. NAGLEVOORT. *Am. J. Pharm.*, **68**, 374–379. — These experiments were undertaken to prove that morphine can be detected and recovered after exposure to the complicated action of decomposing animal bodies, and to substantiate Tamba's statement that ptomaines have no deleterious effect upon the characteristic reactions of morphine. The author states that the popular belief in deterioration of alkaloids by decomposition of cadavers has no foundation upon fact.

Some Results Obtained in the Destructive Distillation of Linseed Oil. By SAMUEL P. SADTLER. *Am. J. Pharm.*, **68**, 465–467. — A preliminary examination only, but sufficient to show that Engler's theory of the origin of our petroleums may be widened, since oils resembling the paraffin class and a scale paraffin were obtained from linseed oil.

Chemical Composition of Oil of Monarda Fistulosa. L. By E. J. MELZNER AND EDWARD KREMERS. *Am. J. Pharm.*, **68**, 539–546. — This paper is in line with others before mentioned in this review, and adds to our knowledge of volatile oils. These investigators are giving results from materials, the source and identification of which is beyond criticism, a matter heretofore too often neglected. From another species of monarda there had been isolated a red crystalline color resembling alizarin. It is of interest to note here that, while most of the oil was yellow, one sample had a permanent dark red color. It contains 52 to 54 per cent. carvacrol, and a titrimetric method of estimating this is given, as well as the results of a long serial fractionation of the residue.

Chemical Composition of Oil of Monarda Punctata. L. By WILLIAM ROBERT SCHUMANN AND EDWARD KREMERS. *Am. J. Pharm.*, **68**, 469–473. — The authors demonstrate the presence of thymol, cymene and some oxygenated compound not yet isolated. Methods and data given in full.

Chemical Analysis of Canada Thistle-Cnicus arvensis. By HERMAN J. PIERCE. *Am. J. Pharm.*, **68**, 529–532. — This preliminary proximate analysis shows the presence of an alkaloidal principle, an organic acid, resin, mucilage, dextrin, pectin, albuminous matter, glucose, fat, wax, caoutchouc, and volatile oil. Starch, tannin, and glucosides are said to be absent.

Rumex Nepalensis (Wall). By O. HESSE. *Am. J. Pharm.*, **68**, 441–445. — The root contains a substance resembling chrysophanic acid. For this he proposes the name *Rumicin*, and for two accompanying substances, *nepalin* and *nepodin*. Methods of isolation and results of analyses are given, and it appears this series of homologous bodies differ by CH_2, while a similar series from an allied group — *Rheum* — differ in O.

Hemlock Oil from Tsuga Canadensis (Carriere). CARL G. HUNKEL. *Pharm. Rev.*, **14**, 34–36. — In previous work there seems to have been uncertainty about the source of the oil, it being described as oil of spruce, and said to come from *Abies canadensis* (*L*) popularly known as hemlock spruce. Incidentally the author mentions that true oil of spruce contains 48.85 per cent. of *l*-bornyl acetate, a quantity only exceeded by that in true oil of hemlock. The latter obtained in small quantities from the leaves and

twigs of *Tsuga canadensis* (*Abies canadensis. Michx.*) consists, for that distilled in September, at about equal parts of *l*-bornyl acetate and *l*-pinene, with small amounts of undetermined substances.

Composition of Oil of Sassafras Bark and Leaves. By Fred. B. Power and Clemens Kleber. *Pharm. Rev.*, 14, 101–104. — Oil was prepared from fresh materials, and the yield from air-dry root bark was found to be 7.4 per cent. The remaining woody tissue gave but 0.9 per cent. of oil having the same composition. They found:

Safrol	$C_{10}H_{10}O_2$,	about 80.0 per cent.
Pinene	$C_{10}H_{16}$	about 10.0 per cent.
Phellandrene	$C_{10}H_{16}$	
Camphor, dextrogyrate	$C_{10}H_{16}O$	about 6.8 per cent.
Eugenol	$C_{10}H_{12}O_2$	about 0.5 per cent.
High Boiling Portion.		
Cadinene, $C_{15}H_{24}$ (?), and residue		about 3.0 per cent.
		100.3

The yield from fresh leaves was but 0.028 per cent., containing pinene, myrcene (?), phellandrene, linaleol, geraniol, acetic, and valerianic esters of these alcohols, cadinene (?) and a paraffin, showing fundamental differences in composition of oils from different parts of the same plant.

Oil from Pycnanthemum lanceolatum (Pursh). By W. G. Correll. *Pharm. Rev.*, 14, 32–33. — The author finds the oil closely resembles that of pennyroyal, but tests for pulegone gave negative results. Carvacrol was isolated and identified. He mentions as a convenient test for thymol and carvacrol in volatile oils the following: Heat 0.01 gram of the oil with 0.01 gram caustic potash and 20 drops chloroform. Both phenols give a purple-red coloration.

Asafœtida. By J. U. Lloyd. *Pharm. Rev.*, 14, 54–58. — This article is of particular interest to the pharmacist, but gives some important data and methods for estimating the purity of asafœtida.

Sanitary Chemistry.

E. H. Richards, Reviewer.

Dietary Studies at the University of Missouri. *U. S. Dept. Agr. Expt. Sta., Bull. No.* 31, 1–24. — The untimely death of Professor Gibson prevented the completion of this inquiry into the bread and meat consumption of the families of the students of the university and in a college club. Farmers living in the country used pork to the extent of 57 per cent. of the total meat consumption, while families having easy access to markets used only 27 per cent. Raised bread formed only 40 per cent. of the total in the case of the latter, while the farmer's families used 53.7 per cent. in the form of biscuit. As is commonly the case in the South, the ratio of fat, as compared with the nitrogenous portion of the food, was too high.

Dietary Studies at the Perdue University. *U. S. Dept. Agr. Expt. Sta., Bull. No.* 32, 1–28. — This is, perhaps, the most instructive of the dietary studies yet published, since it brings out with great clearness the difference,

both in cost and in nutrition, between intelligent and careless provision of food for the family. There is material for reflection in the subjoined table. The small excess of eighty calories, in the case of the mechanic's family, was gained at a cost of eight cents, a sum which, if spent according to the economy of the other family would have furnished 1,235 calories. The fallacy of the assertion, so frequently made, that meat is the most nutritious food is also very well brought out:

	Kind of food material.	Total weight in pounds.	Cost.	Protein in grams.	Fat in grams.	Carbohydrates in grams.	Fuel value in calories.
Teacher's Family.	*Food purchased* . . .	3.69					
	Animal	....	$0.12	75	106	32	1.425
	Vegetable . . .	....	0.06	36	4	317	1.485
	Total	....	.18	111	110	349	2.910
	Waste:						
	Animal	....	....	4	8	..	90
	Vegetable	....	....	1	..	9	40
	Total	....	....	5	8	9	130
Tinner's Family.	*Food purchased* . . .	4.20					
	Animal	....	$0.13	62	143	14	1.640
	Vegetable	....	0.13	44	14	461	2.200
	Total	....	0.26	106	157	475	3.840
	Waste:						
	Animal	....	....	13	22	..	260
	Vegetable	....	....	3	1	67	295
	Total	....	....	16	23	67	555

The Restoration of the Consistency of Pasteurized Cream. By S. M. Babcock and H. L. Russell. *Univ. Wis. Agr. Expt. Sta., Bull. No.* 54, 1–8. — The use of viscogen (sucrate of lime) for restoring the consistency of Pasteurized cream, and for otherwise improving its quality, is discussed from a sanitary standpoint. The authors consider the use of this substance to be legitimate and safe.

Effects of Drouth upon Milk Production. By L. L. Van Slyke. *N. Y. Agr. Expt. Sta., Bull. No.* 105, 131–152. — It will be of interest to the milk analyst and to the food chemist to examine the figures given in this paper on the relative proportion of fat to casein, which seem to show that the lack of sufficient nutrition of the cows, owing to the drying up of the pastures, results in a diminution of the casein from May to August of 0.2 of 1 per cent. During the same time the per cent. of fat increases up to 0.3. Later both increased so that in September and October the casein was 0.3 and the fat was 0.6 higher than in May, but the yield of milk had decreased 33 per cent.

The milk of the cows kept in the stable of the station and fed with green fodder retained a constant composition during the six months.

Steer Feeding Experiments. *Kan. Agr. Expt. Sta., Bull. No.* 60, 107–146. — The large amount of work necessary in experiments on feeding is illustrated in this account of the results obtained on twenty steers. Some lessons for the guidance of human feeding may be learned from the behavior of animals under known conditions. It would appear that a mixed ration of digestible food produces the best animal, and that exposure to the weather requires more food, in order that the standard weight of the animal be maintained.

A Year's Experience with Bacillus No. 41 in General Dairying. By H. W. Conn. *Storrs' Agr. Expt. Sta., Ann. Rep.*, 8, 17–40. **A Study of Rations Fed to Milch Cows in Connecticut.** By Charles D. Woods and C. S. Phelps. *Ibid*, 8, 41–76. **Soiling Experiments with Leguminous and Cereal Crops.** By C. S. Phelps. *Ibid*, 8, 77–92. **Experiments on Fattening Sheep.** *Ibid*, 8, 93–100. **Food Investigations.** *Ibid*, 8, 114–128. **Studies of Dietaries.** By W. O. Atwater and Charles D. Woods. *Ibid*, 8, 129–174. **Results of Analyses of Fodders and Feeding Stuffs.** By Charles D. Woods. *Ibid*, 8, 175–186. **Digestion Experiments with Sheep.** *Ibid*, 8, 187–214.

Purification of Water by Metallic Iron. By C. W. Chancellor. *U. S. Consular Rep.*, 51, 571–576. — This is a description of Anderson's process of water purification by agitation with bits of metallic iron. The process is attracting considerable attention abroad, and has been introduced in several European cities.

Analyses of Waters. *Univ. Cal. Agr. Ept. Sta., Rep. for* 1894–95, 92–111. — This article gives tabulated analyses of a large number of stream, lake, spring, and well waters from various parts of California.

Composition of Certain Mineral Waters in Northwestern Pennsylvania. By A. E. Robinson and Charles F. Mabery. *J. Am. Chem. Soc.*, 18, 915–918. — There are several points both of sanitary and geological interest in the composition of the two waters of which the mineral analyses is here given.

The New Water Supply of the University of Kansas. By E. C. Murphy. *Trans. Kan. Acad. Sci.*, 14, 98–99. — Gives one analysis of water obtained from wells in the vicinity of the University, showing it to be of good quality.

Agricultural Chemistry.

F. H. Thorp, Reviewer.

The Cañaigre or Tanner's Dock. By E. W. Hilgard. *Rep. Agr. Expt. Sta. Univ. Cal.*, 1894–95, 186–195. — This is an extended review of the character, distribution, and cultivation of the plant, together with a study of its chemical composition. Analyses of thirty-four samples of cañaigre and other dock roots are given.

The Value of Leather Refuse. By J. B. Lindsey. *J. Am. Chem. Soc.*, 18, 565–575. — This is the continuation of an investigation begun over two years ago, and part of which has already been published (*12th Ann. Rep. Mass. Agr. Expt. Sta.*, 1894). In the previous article it was shown that raw, roasted, or steamed leather refuse had very little value as plant food. This article gives the results of experiments with leather refuse which has been treated with sulphuric acid of 50° Bé, any excess of acid being neutralized with calcium carbonate. For two years oats were planted in special pots and treated with different fertilizers, for comparison. Analyses of the soil and of the fertilizers and nitrogen determinations of the straw and grain raised in each pot were made. Assuming the amount of nitrogen taken up by the plant when fertilized with sodium nitrate to be 100, the amount taken up when fertilized by dissolved leather was about 70. This would indicate that leather refuse when properly treated with acid is a very good source of nitrogen for plants.

Commercial Fertilizers. *Agr. Expt. Sta. Bull.: Pa., Dept. Agr., Nos.* 4 *and* 5; *Wis., Nos.* 49 *and* 53; *Miss. State Chemist, No.* 9; *R. I. Sta., No.* 33; *La., No.* 39; *N. C., Nos.* 31, 32, 34, 35, *and* 36; *S. C., No.* 24; *Mass. Hatch. Sta., No.* 40. — The foregoing bulletins contain tabulated analyses of fertilizers. In each case the name of the brand and of the manufacturer is stated, and many contain digests of the fertilizer laws.

Cañaigre. By Robert H. Forbes. *Ariz. Agr. Expt. Sta., Bull. No.* 21. — This is an interesting paper on the cultivation, composition, uses, and value of the cañaigre plant. A careful study was made of the formation and distribution of the tannin and coloring matters in the root, the older parts of which, *e. g.*, the bark and heart, were found to be richer in tannin than the newer growth. The green roots average from 8 to 10 per cent. of tannin matters; the leaves, stalks, and seeds containing much less. A study of the formation of tannin, carried on for one season, showed an increase in the percentage of tannin both in wild and in cultivated plants, this increase being constant as long as the plant retains its vitality. The average yearly increase in the yield of dried tannin material from wild plants, as shown by ten samples, was 1.64 per cent., and from cultivated plants was 2.64 per cent. The sprouting of the plant appeared to have no effect upon the amount of tannin. The effect of irrigation was not definitely determined, but it did produce larger roots without apparently lessening the percentage of tannin matter. The yield of tannin matters was influenced, however, by the amount of sunshine to which the plant was exposed. — When the plant dies the tannin matters disappear very rapidly; also heat, air, or fermentation destroys them; hence in preparing samples for analysis they must be dried rapidly at a low temperature. Drying the thinly sliced roots in an oven at 130° F., or in the open air in warm weather, is recommended. Red and yellow coloring matters are present in the root, and the former appears to be strongest in roots high in the percentage of tannin. — The residue, after extracting the tannin matters, has some value as fuel and for fertilizing, but not as a cattle food. Analyses of the dry root and ash are given, which show that the plant draws heavily on the nitrogen, potash, and phosphoric acid in the soil; hence the fertilization of cultivated plants may become a serious item. — The uses of cañaigre and the method of preparing an extract from it are briefly summarized. The cultivation of the plant is more fully considered, and estimates of

the profit to be derived from its culture as compared with those from sugar beets are included. The data for these estimates being insufficient, the results are as yet somewhat problematical.

Cañaigre: The New Tanning Plant. By H. H. Harrington and Duncan Adriance. *Tex. Agr. Expt. Sta., Bull. No.* 38. — This article is very similar to the one described in the preceding abstract, several of the illustrations being reproduced from it. Some additional illustrations show the methods of drying, slicing, and shipping the roots. Data relating to the freezing of the plant are given, also a table of analyses of seventy-two samples from various places, and the analysis of the soil at Monahans, West Texas, where some of the samples grew. Examination of the ash of cañaigre showed that the plant draws more potash than phosphoric acid from the soil, which confirms the results obtained at the Arizona station. Comparative analyses by Lowenthal's method showed the process to be faulty, but its results are thought to be closest to the actual value for tanning purposes. Boiling for one hour with hide powder is considered the best method of extracting the annin.

Chemical vs. Barnyard Manure. By. S. Peacock. *Am. Fertilizer*, 4, 124.

Sulphate of Ammonia from Coke, and as a By-Product of the Iron Industry. *Am. Fertilizer*, 4, 79.

Field Experiments with Fertilizers. By C. S. Phelps. *Storr's Agr. Expt. Sta., Ann. Rep.* 8, 101–110.

General and Physical Chemistry.

A. A. Noyes, Reviewer.

The Conductivity of Solutions of Acetylene in Water. By Harry C. Jones. *Am. Chem. J.*, 18, 623–624. — The author finds that the high electrical conductivity of aqueous acetylene solutions observed by Jones and Allen (*this Rev.*, 2, 35) was probably due, as the reviewer suggested, to the presence of ammonia as an impurity, and that pure acetylene solution has a very slight, if any, conducting power.

Investigation to Determine whether Diphenyliodonium and Thallium Nitrates are Isomorphous. By A. A. Noyes and C. W. Hapgood. *Tech. Quart.*, 9, 236–237. — The great similarity in many other respects of the diphenyliodonium and thallium salts led to this investigation, which consisted in an examination of the crystals separating from solutions of the two nitrates mixed in varying proportions. As the crystals consisted in every case of one or the other of the pure salts, the authors conclude that the substances are not isomorphous.

H. M. Goodwin, Reviewer.

Some Thoughts about Liquids. By Clarence L. Speyers. *J. Am. Chem. Soc.*, 18, 724–737. — The author first discusses the generally accepted kinetic explanation of the vaporization of a liquid, and finds it unsatisfactory in accounting: first, for the escape of vapor; second, for the temperature of

the vapor; and third, for the kinetic energy lost by the particle in getting through the surface of the liquid and beyond the sphere of action of the liquid particles. To explain the phenomenon, a new hypothesis is proposed, the fundamental idea of which is that vapor molecules dissolve as such in the liquid from which they arise in much the same way and following the same law (Henry's law) as an indifferent gas. When a liquid is heated a portion of the heat energy is expended in the formation of dissolved vapor molecules, some of which then escape with small heat of vaporization to the true vapor condition. Following out this idea, it is shown that the concentration of the dissolved vapor is equal to the concentration of the liquid itself, *i. e.*, the solvent is to be regarded as condensed vapor. For details, reference must be made to the original paper. The question as to the cause of the gaseous and liquid or "condensed gaseous" state is left unanswered, the author being inclined to reject all kinetic hypotheses and to regard matter from Ostwald's point of view as different, aggregates of energies.

An Empirical Relation between Melting Point and Critical Temperature. By F. W. Clarke. *Am. Chem. J.*, **18**, 618–621. — The author compares the thermometric lengths of the solid and liquid states of various substances whose melting point and critical temperature have been determined, *i. e.*, he determines the ratio of their critical temperature to their melting point measured on the absolute scale. It appears as a result of such a comparison, that for many substances, namely, nitrogen, carbon monoxide, argon, benzene, acetic acid, and others, this ratio is approximately equal to *two*, *i. e.*, the absolute temperature limits of the solid and liquid states are approximately equal. This, however, is not general, as there are numerous exceptions in which the ratio is greater and less. No general conclusions can be drawn from the material at hand.

On the Specific Gravities of Mixtures of Normal Liquids. By C. E. Linebarger. *Am. Chem. J.*, **18**, 429–453. — The question as to the cause of the change of volume on mixing two liquids which do not react chemically is discussed, and the probability of the simplest relations holding for mixtures of "normal" liquids emphasized. To throw more light on this subject, the author determined by the pyknometer method the density of twenty-four binary mixtures of different normal organic liquids, the mixtures varying in composition from one pure constituent to the other. A comparison of the observed density with that calculated by the formula for mixtures shows, in the majority of cases, the observed density to be less than the calculated, thus indicating a slight increase in volume. This, the author points out, is what theory would lead one to predict, regarding the phenomenon either as a result of diminution of surface tension caused by the solution of one liquid in another or as a result of osmotic pressure. The maximum increase in volume should result in mixtures of equal proportions of the two constituents, and this was in general found to be the case. Exceptions which are difficult to explain occurred in some cases, however. The author points out that, if the specific gravity of a mixture of a well-established "normal" liquid and a second liquid differs widely from that calculated by the rule of mixtures, the second liquid is probably more or less "associated."

Apparatus for the Rapid Determination of the Surface Tension of Liquids. By C. E. Linebarger. *Am. J. Sci.*, **152**, 108–123. — (See *this Rev.*, **2**, 38.)

On the Surface Tension of Mixtures of Normal Liquids. By C. E. LINEBARGER. *Am. J. Sci.*, **152**, 226–228. — This article contains the results for six mixtures of different normal liquids obtained by the author's method for determining surface tension. (See above reference.) The mixtures varied in composition from one pure constituent to the other. The measurements show that the surface tension of a mixture cannot be calculated by the rule of mixtures from the superficial tensions of its components. The deviations for mixtures of benzene and toluene are less than 0.2 per cent., however.

Melting Points of Aluminum, Silver, Gold, Copper, and Platinum. By S. W. HOLMAN, WITH R. R. LAWRENCE AND L. BARR. *Tech. Quart.*, **9**, 24; also *Proc. Am. Acad. Arts and Sci.*, **1895**; *Phil. Mag.*, **42**, 37–52. — The method employed consisted in measuring the thermoelectric force of a platinum-rhodium couple, one junction of which was maintained at 0°, the other at the temperature of the molten metal, by a very convenient modification of Poggendorff's compensation method. The form of apparatus for determining the boiling points of sulphur was essentially that described by Griffiths. For melting the metals (except platinum) a furnace especially constructed with reference to securing uniform heating and obviating oxidation of the metal was devised. The platinum was fused by an oxy-hydrogen flame directed on a piece of lime. All metals were of a high degree of purity, except, perhaps, the platinum. For computing the temperatures from the thermoelectric data obtained Holman's exponential and logarithmic formulæ were both used. (See *Tech. Quart.*, **8**, 353; *Phil. Mag.*, **1895**.) As a basis for interpolation, Holborn and Wien's value for the melting point of gold 1,072°, and Callendar and Griffith's value for the boiling point of sulphur ($444°.53 + 0.082\ [H - 760]$), were assumed correct. In the following table are given the final results obtained (the mean values calculated by the two formulæ referred to above), together with values found by other observers, for comparison. The authors give the values as provisional, subject to future correction if the assumed value 1,072° for gold is found in error. The values are, however, undoubtedly the most reliable yet published:

Authority.	Date.	Method.	Metals.				
			Al.	Ag.	Au.	Cu.	Pt.
Holman, Lawrence, and Barr . .	1895	Th-el.	660°	970°	1,072°	1,095°	1,760°
Violle	1879	Sp. Ht.	....	954	1,035	1,054	1,775
Ledebur	1884	Sp. Ht.	....	960	.....	1,100	.....
LeChatelier	....	Th-el.	635	....	[1,035]	.....	.....
Callendar	....	.....	....	[945]	1,037	.....	.....
Erhard and Schertel	....	.....	....	954	1,075	.....	.....
Barus. By log. equation . . .	1894	Th-el.	641	985	1,090	1,095	1,783
Barus. By Equation 3	....	.....	....	986	1,091	1,096	1,757
Holborn and Wien	1892	Th-el.	....	968	1,072	1,082	.....

METALLURGICAL CHEMISTRY.

H. O. HOFMAN, REVIEWER.

The Equipment of Mining and Metallurgical Laboratories. BY H. O. HOFMAN. *Trans. Am. Inst. Min. Eng.*, **25**, 301–327. — The mining and metallurgical laboratory is defined as a place in which mechanical and chemical tests are made on ores, fuels, and furnace materials; the necessity of such a laboratory in connection with teaching is insisted; the principles which should govern its construction are discussed, and finally the laboratory of the Massachusetts Institute of Technology is described and illustrated.

Further Experiments for Determining the Fusibility of Fire Clays. BY H. O. HOFMAN. *Trans. Am. Inst. Min. Eng.*, **25**, 3–17. — The experiments described in the paper were made according to Seger's direct method. The Seger furnace, crucible, and cones for refractory clays are described; and the manner of preparing samples for a test and the method of working the furnace in order to melt down severally the different cones by varying fuel and pressure of blast are given in full; finally the results of tests made with thirty leading American fire clays are recorded in a table, with the chemical analyses of twenty-two clays. The results make a very favorable showing for the leading American fire clays.

Zinc in Slags. BY A. C. CANBY. *Eng. Min. J.*, **62**, 292. — This is a contribution to the discussion of the composition of zinc-bearing slags made in the smelting of silver-bearing lead ores. Examples are given showing the following range of composition: SiO_2, 26.0 to 30.0; FeO, 22.7 to 33.9; CaO, 14.0 to 24.8; ZnO, 14.1 to 21.0. The silica is seen to run very low and the lime very high considering the large amount of zinc.

The Ducktown Ore Deposits and the Treatment of Ducktown Copper Ore. BY C. HENRICH. *Trans. Am. Inst. Min. Eng.*, **25**, 173–245. — The second part of the paper (pp. 220–245) discusses the present treatment of the ore and the one proposed by the author. The ore is a pyrrhotite, with some chalcopyrite occurring in micaceous slate and hornblendic rock; it is crushed, passed over a picking table to remove barren matter, then roasted in heaps containing about 200 tons, the excess of fines formed are desulphurized in shelf-roasting furnaces. The roasted ore contains about 3.5 per cent. copper, and is smelted with 10 per cent. quartz in two Herreshoff furnaces (each treating 100 tons charge in twenty-four hours) to a 50 per cent. copper matte. The flue dust formed is considerable, on account of the high pressure of blast (14 to 16 ozs.); it is not treated, as it runs too low in copper. Occasionally the matte is concentrated, in a circular water-jacket blast furnace, to black copper and 70 per cent. or 80 per cent. copper matte. The author estimates that only 23 per cent. of the copper in the roasted ore is saved in the matte. He proposes to crush the ore coarsely and to screen out the fines (under $\frac{3}{8}''$), to pick over the coarse ore, separating it into waste, slaty (acid) ore, and pyrrhotite (basic) ore. The fines are to be roasted in an improved Hasenclever furnace, the two coarse ores separately in stalls. The roasted ore is to be smelted in a furnace 120″ by 42″ at the tuyère-level, having sixteen tuyères 4″ in diameter. With a pressure of from 7 to 8 ounces and a readily fusible mixture, from 200 to 240 tons charge could be smelted

producing little flue dust. By correct proportioning of acid and basic ore no barren flux need be added to the charge. The first matte produced is to run not higher than 20 per cent. copper, whereby slag practically free from copper is made. The matte is to be crushed, rolled, roasted in an improved Hasenclever furnace, mixed in a pug mill with from 15 to 20 per cent. clay, formed by a machine into bricks, kiln-burned, and smelted for 70 per cent. matte and some black copper, or much black copper and some 80 per cent. matte, and rich slag to be returned to the ore furnace. By this treatment not more than 7 per cent. of the copper in the ore would be lost. The cost by the present method with a 200-ton plant is estimated at $2.56 per ton, by the improved method at $2.66; by the present method, however, the ore must contain 3 per cent. copper, to insure against loss; by the improved method an ore to pay expenses must run 2⅛ per cent. copper.

Matte Smelting in California. By H. Lang. *Eng. Min. J.*, 62, 78–79, 103–104. — The paper is a record of pyritic smelting carried on by the author at the works built by himself at Keswick, California. They are erected upon level ground, instead of on a hillside as is commonly the case, and the motive power is electricity. The ores carry both silver and gold; they are of two kinds — oxides low in copper: S, 13.41–2.49; Fe in FeS_2, 11.40–2.09; Fe_2O_3, 48.22–70.88; Zn, 0.24–0 21; SiO_2, 9.45–8.57; Al_2O_3, 0.60–1.39; H_2O, etc., by diff., 14.00–13.43 — and sulphides carrying from 3 to 7½ per cent. copper: S, 45.66; Fe, 36.97; Zn, 3.41; SiO_2, 5.60; Al_2O_3, 1.57. As they run low in silica and high in iron, much acid flux has to be used to form a desirable slag. Gold-bearing quartz from neighboring mines furnishes the necessary silica. The furnaces (*this Rev.*, 2, 54) are 15′ long, 3′ wide, 7½′ high from tuyères to feed-floor and 1′ deep below the tuyères. The walls are vertical; they consist of water jackets and brick walls, cooled by vertical water pipes 7″ apart. The blast is heated to 500° F. by drawing the air with a Sturtevant fan through an arched chamber, while slag pots containing liquid slag are passed along in an opposite direction. The fuel is coke ($12 a ton) and wood ($3 a cord); the smallest amount of coke (when no wood was used) was 1½ per cent. The slag made was a singulo silicate. The furnace put through in twenty-four hours 65 charges of 4,000 pounds (1,400 sulphide ore, 700 oxide ore, 500 gold quartz, 700 slag, 700 matte, 100 coke, 75 to 150 wood); the concentration of sulphide ore was 4 : 1, of matte 3 : 2. The cost was $1.26 per ton of mixture, or $1.97 per ton of ore. The composition of the slag was: Cu_2S, 0.25; FeS, 7.57; FeO, 45.06; ZnO, 4.03; Al_2O_3, 10.72; SiO_2, 30.43; CaO, trace; MgO, 0.42; K_2O, 0.30; Na_2O, 2.08; of the gases: SO_2, 9.01; CO_2, 10.85; CO, 3.27; H, 2.55; O, 0.00; N, etc., 74.52. The matte assayed 40 per cent. copper.

The Anaconda Electrolytic Copper Refining. *Eng. Min. J.*, 62, 271–274. — This plant was lately completed by H. Thofern. It consists of two independent parts separated by a free space of 100′ as a protection against fire; each covers a space of 6,500 square yards, and contains 600 electrolytic tanks. A current of from 10 to 20 amperes per square foot is used for refining. It is obtained from seven Westinghouse generators, representing a total of 1,790 K. W., corresponding to 2,942 H. P. The tanks are 2.50 m. long, 1.50 m. wide, and 1.00 m. deep; they are of wood, and are lined with lead. Ten tanks are placed in a row. Each row is set on its own foundation, and the joints in the woodwork of tank and foundation are soaked in insulating mate-

rial before they are put together. Ten rows make one set (= 100 tanks), and two sets make one system (= 200 tanks). Each system works independently; there are six in all (= 1,200 tanks); each produces as a maximum thirty-five tons of electrolytic copper in twenty-four hours. The rows are built on an inclined plane, and the solution of each row is circulated separately, flowing from the uppermost tank to the lowest, where it is collected in a sump, to be pumped by compressed air into the distributor placed above the topmost tank. — The tanks of each system are connected in series. On each side of a tank along the top run two conductor rods. The electrodes are suspended from flat-iron bars. The anode rods of one tank form the cathode rods of the next following. The tanks are loaded and unloaded from an overhead electric crane spanning the width of the hall; all anodes of a tank (about four tons) are lowered together, and the corresponding cathodes are removed in the same way. The anodes are blister copper, with 98 per cent. Cu, 110 ounces Ag, and 0.33 ounces Au per ton, the impurities being As, Sb, Fe, Pb, Te, and Se. The cathode copper has a conductivity of 98 per cent. (Mathieson standard), a tensile strength of 64,000 to 65,000 pounds per square inch; it endures eighty twists in 6″ of No. 12 wire, with an elongation of 1¼ per cent. The impurities collecting in the electrolyte are removed at intervals by chemical means; the process used is not given. The anode mud is refined by first screening off scrap copper, then boiling with sulphuric acid, steam and air, filtering, and washing, the second operation being repeated. The purified doré silver is dried, melted down in a reverberatory furnace, cast into ingots, to be parted with sulphuric acid, giving silver of 999 fineness and a high-grade gold. The cost of refining, including parting of doré silver, is $14 per ton of copper produced. The paper concludes with an outline of Thofern's improvement of the Elmore process for electro-depositing solid sheet copper on a revolving cylindrical cathode 8′ long and 3′ in diameter. He uses a current of from 50 to 100 amperes per square foot, and allows jets of electrolyte under pressure to play on to the immersed cathode. When the deposit is about 1″ thick it is removed, flattened out, and rolled into a sheet, or first cut into strips, and then rolled and drawn into wire.

The Lixiviation of Silver Ores by the Russell Process at Aspen, Colorado. By W. S. Morse. *Trans. Am. Inst. Min. Eng.*, 25, 137–146, 993–997. — The paper is a complete record of the treatment of 30,000 tons of ore, an average analysis of which, representing nearly 1,000 separate lots, showed the following composition: Pb, 2.277; SiO_2, 21.663; $BaSO_4$, 20.924; CaO, 10.992; MgO, 4.245; Fe, 10.025; Zn, 2.854; Cu, 0.161; S, 8.105; and 27.918 ounces Ag per ton. The ores will be seen to be rich in baryta, lime, and magnesia. They were dried in Stetefeldt shelf dry kiln, and roasted with 12.2 per cent. salt (dried in the same way as the ore) in a Stetefeldt furnace. The total silver loss from handling and roasting the ore was 9.157 per cent.; the author attributes 1 per cent. to mechanical loss in handling and the rest to volatilization in roasting. — Mr. Stetefeldt (p. 993), commenting on these figures, argues that the mechanical loss must have been greater, as in the Stetefeldt furnace such a high volatilization loss does not take place, a statement which Mr. Morse (p. 996) does not accept. — The leaching plant had seven leaching tanks (17′ inside diameter and 9′ deep, holding 58.19 tons of roasted ore), six precipitating tanks for solution (12′ diameter and 9′ deep), and six for wash water (8′ diameter and 10′ deep), four storage tanks for solution (12′ diameter and 8′ deep), and two for sulphides (10′ diameter and 3′

deep). In leaching, a charge of ore required 22.5 cubic feet water, or 60″ in depth of tank for saturation; after removing the soluble salts 50″ were sufficient. The mode of operation was to run one third of the water into the vat, then charge the ore, add the rest of the water, and apply the solvents in the following order: 3 vols. warm hyposulphite solution (1.8 per cent. $Na_2S_2O_3$ + 5aq), 1 vol. Russell solution (0.5 per cent. $CuSO_4$ + 5aq), 1 vol. hypo, 1 vol. Russell, 2 vols. hypo, and then the final wash-water. The average time of leaching was 100 hours, the rate of leaching 13″ per hour. In sampling the ore in the vat, cores 1¼″ in diameter were taken through the entire depth of the charge with a brass tube having a valve at the bottom. In order to obtain satisfactory samples of the leached ore, one half was sluiced out, and then three samples were taken from the exposed surface: top samples and bottom samples, 1′ from top and bottom, and a general sample over the entire surface, which was 7′ deep and 17′ wide. Laboratory tests on roasted ore as it came from the furnace showed, with hypo, an extraction of 52.5 per cent.; with Russell solution, one of 78.4 per cent. After the ore had been banked up on the cooling floor for 102 hours, the figures changed to 78.9 per cent. and 89.8 per cent., respectively. It was found that in the mill where the ore is first leached with water, before the chemicals are applied, the extraction by hypo and by Russell solution was 20.1 per cent. and 3.0 per cent., respectively, lower than in the laboratory. In carrying out the laboratory tests, in the same way as in the millwork, the decrease in extraction was found to be 14.6 per cent. and 1.2 per cent., respectively, making the mill results 5.5 per cent. and 1.8 per cent., respectively, lower than the washed-ore samples. An explanation for this is given in a separate paper by the author (see below). The three silver-bearing products of the mill, viz., solution sulphides, wash-water sulphides, and lead carbonates, assayed 3,790, 2,875, and 432 ounces silver per ton. The cost of treatment per ton of ore was $2.8768.

The Effect of Washing with Water upon the Silver Chloride in Roasted Ore. By W. S. Morse. *Trans. Am. Inst. Min. Eng.*, 25, 587–594, 1027–1036. — The object of the paper is to find an explanation for the "going back" of the chloridation, which means the decrease in extraction of silver from chloridized ore when this has been washed with water to remove the soluble salts, the silver having been changed from a form soluble in sodium hyposulphite to one insoluble in it and slowly soluble in the Russell solution — the amount at Aspen, Colorado, being 14.60 ounces with ore assaying 78.92 ounces silver per ton. The author seeks the cause for this in the presence of undecomposed base metal sulphides, which convert silver chloride into silver sulphide, and brings mill data and the results of experiments to bear out his theory. Mr. Godshall (p. 1027) attacks the theory, his explanation being that the presence of sulphurous acid has much to do with making the silver compound insoluble.

The Sulphuric Acid Process of Refining Lixiviation Sulphides. By F. P. Dewey. *J. Am. Chem. Soc.*, 18, 643–654. — The treatment of precious metal sulphides produced in the leaching of silver ores with sodium hyposulphite has always been a weak point of the Patera process, and the sulphides produced in the Russell process had to be sent to smelting works, as treatment by roasting and melting was out of question, on account of the large amount of base metal present. The Dewey-Walter Refining Company has successfully treated the sulphides

obtained in the Marsac Mill, Park City, Utah, by the Russell process ever since 1893. In 1894 the 116,519.5 pounds sulphides produced assayed 9,827.4 ounces silver and 11.225 ounces gold per ton, 27.17 per cent. copper and 0.33 per cent. lead. The process consists of the following six main operations: "(1) Boiling the sulphides with strong sulphuric acid in an iron pot; (2) dissolving out the sulphates of copper and silver in a lead-lined tank, leaving a residue containing the gold and lead, and also rich in silver; (3) precipitating the silver out of the filtered solution by copper plates; (4) sweetening, drying, pressing, and melting the cement silver; (5) treatment of the solutions after the removal of silver to crystallize the copper sulphate and recover the excess of acid for re-use; (6) treatment of gold-bearing residues. — The construction of plant, the details of the operations, and the statistics are given in full."

Milling Arizona Gold Ores with a Colorado "Stamp Mill." By W. S. Morse. *Trans. Am. Inst. Min. Eng.*, 25, 130–136. — A detailed description of gold amalgamation with a Gilpin County mill. The paper, replete with technical details, has special interest, as this form of mill is confined to a very small district in Colorado.

Gold Milling in the Black Hills of South Dakota and at Grass Valley, California. By T. A. Rickard. *Trans. Am. Inst. Min. Eng.*, 25, 906–928. — A detailed description of the work done in these two districts, supplementing the papers published in 1888 by H. O. Hofman (*Trans. Am. Inst. Min. Eng.*, 17, 498) and in 1894 by E. R. Abadie (*Trans. Am. Inst. Min. Eng.*, 24, 208).

The Reduction Plant for Pyritic Gold-Bearing Ores at Gibbonsville, Idaho. By B. MacDonald. *Eng. Min. J.*, 62, 319–320. — This is a description of a plant treating 100 tons of gold ore worth $100 a ton by battery amalgamation (saving 40 per cent. of the gold), followed by concentration and chlorination. Of special interest are the stamping in a narrow double-discharge mortar, to avoid sliming of the ore, the use of a spitz-kasten with five spigot discharges, which are separately treated on Frue vanners, and the dead roasting in a Pearce turret furnace. Full statistics of each operation accompany the paper.

The Present Condition of Gold Mining in the Southern Appalachian States. By H. B. C. Nitze and H. A. J. Wilkens. *Trans. Am. Inst. Min. Eng.*, 25, 661–796, 1016–1027. — The metallurgist will be much interested in the illustrated detailed description of the amalgamating and chlorinating processes in use at the Haile Mine, South Carolina, especially in the chlorinating, as it was there that the modification known as Thies process was worked out successfully by the inventor. It has since become one of the standard methods of extracting gold from roasted concentrates by means of chlorine water.

Treatment of Roasted Gold Ores by Means of Bromine. By R. W. Lodge. *Trans. Am. Inst. Min. Eng.*, 25, 86–89. — The paper is a record of laboratory experiments with gold-bearing arsenopyrite concentrates (74.4 per cent. AsFeS) carrying considerable pyrite, some galena and chalcopyrite. The material used contained 2.31 ounces gold per ton. Treatment by barrel chlorination gave an unsatisfactory extraction, consumed much chlorine; all

the gold could not be precipitated, and what was recovered was very base. With bromine the work was satisfactory. The experiments cover roasting, concentration of bromine solution, and time required to extract the gold. The preliminary tests were made on 500 grams of ore, and the final tests on 15 kilograms. In the former, 1.5 cc. bromine in 500 cc. water gave an extraction of gold of over 90 per cent. in 5½ hours; in the latter, 35 cc. bromine in 15 kilograms of water showed in 5½ hours a gold yield of 92.18 per cent., based on the assay of the tailings, while only 80 per cent. actual gold were recovered from the solution, owing probably to the presence of copper.

The Engelhardt Bromine Gold Extraction Process in Operation. By D. C. Pret and H. Trachsler. *Eng. Min. J.*, **62**, 295. — This is a brief outline of the process as carried out on roasted telluride ores at the bromination works of Pret, Trachsler & Co., La Plata, Colorado. An average sample of 100 tons of ore showed the following composition: SiO_2, 8.05; Fe_2O_3, 10.0; CaO, 1.05; MgO, none; Al_2O_3, 3.7; S, 2.80; total, 98.05 — the difference being covered by copper, arsenic, chromium, titanium, tellurium, gold (1.25 to 2.00 ounces per ton), and silver (0.5 to 1.0 ounce per ton). The dissolving liquor charged into the revolving barrels contains from 0.15 to 0.25 per cent. bromine, bromination takes from 1½ to 3 hours, and filtering from 35 to 45 minutes. The gold is precipitated, in the usual way, by sulphurous acid and hydrogen sulphide. The extraction ranges from 90 to 96 per cent. After experimenting with barrel chlorination, this process was adopted, as the bromine solution acidified with hydrochloric acid, "with the addition of soda or any other cheap acid producing alkali or alkaline earth," gave a better extraction, more uniform and quicker results, and proved cheaper as to chemicals, especially on account of the lower freight charges and the greater convenience to the operator.

The Present Limitations of the Cyanide Process. By C. W. Merrill. *Trans. Am. Inst. Min. Eng.*, **25**, 102–106. — The author presents the conclusions arrived at by him in an extended experience in the laboratory, and at works, as to the applicability of potassium cyanide as a solvent for gold ores. Coarse gold, not being readily soluble, should be first extracted by amalgamation; the yield in leaching with suitable ores will be about 85 per cent. Unfortunately even dilute solutions have a solvent effect on base-metal compounds, such as those of copper, zinc, iron, and manganese. These foul the solution, and its dissolving power decreases, as shown by Maclaurin, with its viscosity; further, from a foul solution gold is precipitated with difficulty by means of zinc. Mixing the ore with lime counteracts to some extent the bad effect of iron and manganese, but no means have as yet been discovered to counteract the effects of copper and zinc. Soft and slimy ores often give a good extraction when crushed coarse; roasted ores often fail to give a fair yield in gold, on account of the particles fusing together, even with a most careful roast. The behavior of cyanide with ores containing galena, blende, oxide lead ores, pyrite, and tellurium compounds has not yet been satisfactorily studied. The ores best suited are oxide ores containing no harmful substances, roasted tailings from gold mills, and finally siliceous ores, all of which must contain the gold in a finely divided condition.

A Device for Cyanide Experimenters. By W. J. Sharwood. *Eng. Min. J.*, **62**, 613. — The device consists in affixing to a glass plate of a given area gold foil, and exposing this to the action of the solvent. Square micro-

scope cover-glass (Chance's ¾ inch giving an area of 3.7 sq. cm.) is cleaned, coated with an alcoholic solution of shellac, and pressed upon a smooth sheet of gold leaf when most of the alcohol has evaporated. The shellac is allowed to harden, and the ragged edges of the foil are rubbed off. Gold foils thus fixed represent uniform weights, thicknesses, and surfaces, and are treated in seven eighths or one inch test tubes with from 10 to 30 cc. of solvent.

The Cyanide Process as Applied to the Concentrates of a Nova Scotia Gold Ore. By R. W. Lodge. *Trans. Am. Inst. Min. Eng.*, 25, 90–94. — Nova Scotia gold ores contain, as a rule, considerable gold-bearing arsenopyrite, which is generally allowed to pass off with the tailings to the dump. The laboratory experiments described were carried out to see how much gold could be saved from mill concentrates by cyanide treatment and with how much loss of the reagent. The material experimented upon contained 66.5 per cent. arsenopyrite, considerable pyrite, some galena and chalcopyrite, the gangue being an argillaceous schist, and slate with some quartz. The screen analysis showed that 92.7 per cent. of the ore passed through an 80-mesh sieve. The solutions used contained 1 per cent potassium cyanide. The tests were made in stationary vats and in revolving bottles; the solutions were added all at once and at different periods, and the time of contact was varied. The best results as regards extraction (93.68 per cent.) and consumption of cyanide (4.44 per cent.) were obtained in revolving bottles.

The Cyanide Process at the Utika Mine. By T. N. Smith. *Min. Sci. Press*, 73, 258. — A short description of the process as applied to the working of battery slimes, 85 per cent. of the gold being saved at a cost of $3.50 a ton. The solution, 10 pounds cyanide in 1,600 pounds water, is made up in an agitator, 2,000 pounds of ore are added, and the muller kept going for six hours. The contents is then run through a filter press and washed.

The Siemens and Halske Process of Gold Recovery. By C. Butters. *Eng. Min. J.*, 62, 292. — The author contradicts the statement made (by *Eng. Min. J.*, 61, 177; *this Rev.*, 2, 27) that the Siemens and Halske process for electro-depositing gold from cyanide solutions had been a failure in South Africa. At the Worcester mine, in the past two years, 70,000 tons of tailings have been treated, and for several months past 25,000 tons a month. About the beginning of 1897 there will be treated every month about 100,000 tons tailings and slimes. At the Robinson mine 6,000 tons of slimes are treated monthly, giving 800 tons of cyanide liquor per day containing from 4 pennyweights to 15 and 18 grains gold per ton; the gold from liquor with 4 pennyweights a ton is reduced to 8 or 9 grains; and with 18 grains, to 3 or 4 grains. The author says the concentration, acidity, or alkalinity of solution have no influence on the result, organic matter alone having to be avoided.

Notes on the Magnetization and Concentration of Iron Ore. By W. B. Phillips. *Trans. Am. Inst. Min. Eng.*, 25, 399–423. — The part of the paper that has a chemical bearing is the reduction of ferric oxide in red fossiliferous iron ore to magnetic oxide by means of producer gas in a modified Davis-Colby shaft roasting furnace, and thus making it suited for magnetic concentration. The furnace treated 110 tons of ore in 24 hours, with an outlay of 3 tons of good coal. The concentrator produced from roasted ore with 45 per cent. Fe and 30 per cent. SiO_2 an enriched product with 58.9 per cent. Fe and 11.5 per cent. SiO_2.

Geological and Mineralogical Chemistry.

W. O. Crosby, Reviewer.

The Geologic Efficacy of Alkali Carbonate Solution. By E. W. Hilgard. *Am. J. Sci.*, 152, 100–107. — The author does not regard the derivation of the alkali carbonate of natural waters from alkali silicates as an adequate explanation, and he discusses the possibilities of a much easier mode of formation, which explains both the very frequent occurrence of carbonated alkali waters and the presence of the accompanying salts of neutral reaction. The starting point for the new view is found in the frequently observed crystallization of gypsum from evaporation residues of intensely alkaline reaction, a state of things completely contrary to the play of affinities as set forth in the standard works of reference. The fact that normal alkali carbonates are described as standard precipitants of the earths, even in analytical operations, suggested that the presence of an excess of carbonic acid, or of "super carbonates," might be concerned in the apparent anomaly. Following in the footsteps of Mueller, the author found that on passing CO_2 through neutral solutions of potassium and sodium sulphates in which calcic carbonate was mechanically suspended, an abundance of gypsum was formed, and the solutions became intensely alkaline. The substitution of alkali chlorides for sulphates did not alter the main result. The almost universal coöccurrence of the three factors, viz., calcium and magnesium carbonates, alkali chlorides and sulphates, and free carbonic acid in nature, indicates that this simple process of formation of the alkali carbonates must be of vastly more frequent occurrence than that which presupposes the existence of soluble alkali silicates. The reaction goes back to a considerable extent when the solutions are evaporated, especially by boiling, but no amount of boiling will entirely destroy the alkaline reaction. The practical limit of the reaction is reached at 8 grams of alkali carbonate per liter, and the existence of this limit prevents this simple mode of producing sodic carbonate from being technically useful, as it would not pay to evaporate such dilute solutions. The author notes, however, that nature performs this service to humanity in the arid regions, from which trona, urao, and kara have for ages been imported into Europe. The relations of these principles to the properties of soils and their bearing upon many geologic problems are discussed in the concluding pages of the article.

The Bearpaw Mountains of Montana. By Walter Harvey Weed and Louis V. Pirsson. *Am. J. Sci.*, 152, 136–148, 188–199. — This second paper on the subject embodies, in the first part, descriptions of augite syenite, intrusive trachyte, nepheline basalt, and leucitite. The leucitite, or olivine-free leucite basalt, is so rare a rock on this continent as to give it a special interest. The description of the beautiful crystalline structure of the leucite is supplemented by an exhaustive bulk analysis of the rock, by Dr. H. N. Stokes, in which more than twenty constituents are determined. Analyses of four other occurrences of leucite rocks are quoted for comparison, the closest agreement being with the leucite basanite of Mount Vesuvius. The second part of the paper is devoted to a series of tinguaite dikes, with two new and complete analyses by Dr. Stokes.

On the Composition and Structure of the Hamblen County, Tennessee, Meteorite. By George P. Merrill. *Am. J. Sci.*, 152, 149–153. — This meteorite is a mesosiderite, embracing both metallic and stony

portions, which were separately analyzed. Microscopic examination indicates the presence of two pyroxenic minerals (enstatite and diallage), olivine, and a plagioclase feldspar, which is proved by analysis to be anorthite. No fewer than nine species are recognized in the meteorite as a whole.

On Northupite; Pirssonite, a New Mineral; Gaylussite and Hanksite from Borax Lake, San Bernardino County, California. By J. H. PRATT. *Am. J. Sci.*, 152, 123–135. — This paper is an important contribution to the mineralogy of this remarkable locality, which has yielded over twenty species, five of them — colemanite, hanksite, sulphohalite, northupite, and pirssonite — being new to science. The careful analyses of northupite yield, with great exactness, the formula $MgCO_3,Na_2CO_3,NaCl$. In like manner pirssonite, described here for the first time, gives $CaCO_3,Na_2CO_3,2H_2O$. Gaylussite, an old and well-established species, receives here only a crystallographic description. Hanksite was first described a decade since, but not until now has pure material been submitted to analysis, yielding the somewhat complicated formula $9Na_2SO_4.2Na_2CO_3.KCl$. It is scarcely possible that potassium and sodium are isomorphous in this mineral, for potassium seems always to be present in quantity just sufficient to form KCl with the chlorine. The compound furnishes a very interesting example of the exceptionally rare occurrence of three acid radicals in a mineral.

Wardite: a New Hydrous Basic Phosphate of Alumina. By JOHN M. DAVISON. *Am. J. Sci.*, 152, 154–156. — This is a secondary species encrusting decomposition cavities in nodules of massive variscite. Analysis gives the formula $P_2O_5.2Al_2O_3.4H_2O$.

Italian Petrological Sketches. By HENRY S. WASHINGTON. *J. Geol.*, 4, 541–566. — This paper is devoted to the volcanic district of which Lake Bolsena, northwest of Rome, is the center. The volcanics described are chiefly leucitic rocks, trachyte and andesite, and intermediate types, including vulsinite, of which a single original analysis is given, while twelve other analyses are quoted for comparison.

On the Analysis of the Deposit from a Chalybrate Water. By E. C. CASE. *Trans. Kan. Acad. Sci.*, 14, 36–37. — The water in question is that of a well forming part of the water supply of the city of Lawrence, Kansas. Analysis of the water shows the following solids in parts per 100,000: SiO_2 and insol., 4.50; $Fe_2O_3 + Al_2O_3$, 3.45; $CaSO_4$, 9.31; $CaCO_3$, 15.03; $MgCO_3$, 6.72; NaCl, 14.43 = 53.44. There are in all 35.15 parts of CO_2, and the reviewer suggests that the iron also is probably carbonated, since the author states in a later paragraph that in the freshly drawn water the iron is always present in the ferrous state. The precipitation of the iron as ferric hydrate would thus naturally follow the exposure of the water to aëration. The homogeneous deposit formed to a thickness of two feet in the bottom of the well is chiefly limonite, as the following analysis shows: SiO_2 and insol., 19.30; $Fe_2O_3 + Al_2O_3$, 46.95; $CaSO_4$, 0.25; $CaCO_3$, 7.32; $MgCO_3$, 0.75; NaCl, 0.60; H_2O (100° C.), 9.15; H_2O (230° C.), 14.40; Org. Mat. (undet.), 1.28 = 100.00.

On the Composition of a Natural Oil from Wilson County, Kansas. By F. B. DAINS. *Trans. Kan. Acad. Sci.*, 14, 38–39. — The author gives the results obtained in fractionating by distillation the oil from the Nor-

man well, which is 800 feet deep and yields a maximum of two barrels per hour.

On the Composition of the Water from a Mineral Spring in the Vicinity of "the Great Spirit Spring," Mitchell County, Kansas. By E. H. S. Bailey and Mary A. Rice. *Trans. Kan. Acad. Sci.*, 14, 40–41. — The analysis, calculated to grains per gallon, shows: SiO_2 and insol., 0.892; Fe_2O_3 + Al_2O_3, 0.969; $CaCO_3$, 40.263; $MgCO_3$, 5.915; $MgSO_4$, 99.093; Na_2SO_4, 143.065; K_2SO_4, 22.860; NaCl, 711.147 = 1,024.204. An analysis of the Great Spirit Spring is quoted to show the close agreement of the two springs.

Coal in Atchison County, Kansas. By E. B. Knerr. *Trans. Kan. Acad. Sci.*, 14, 216–217. — This coal is from a recently discovered bed, sixteen to twenty inches thick, near the city of Atchison. Analysis shows: Water, 3.43; volatile, 30.02; fixed carbon, 55.79; ash, 10.76 = 100.00. The coal contains very little sulphur, and this is combined as calcium sulphate, and therefore unobjectionable. The specific gravity of the coal is 1.17, and it is very hard for a bituminous coal. Two other analyses of Kansas coals may be found on pages 243 and 259 of this volume.

A Mad Stone. By T. Proctor Hall and Ernest E. Frisk. *Proc. Iowa Acad. Sci.*, 3, 45–47. —Describes a light-colored absorbent rock from the Mammoth Chimney Mine. It adheres very strongly to the tongue, and seems to possess in other respects the characters of the so-called mad stones. By drying and then saturating with water the porosity of the stone was found to be about 60 per cent. of its total volume. Duplicate analysis gave: SiO_2, 95.53 and 96.14; Al_2O_3, plus traces of Fe_2O_3, 4.59 and 4.01.

The So-Called Socorro Tripoli. By C. L. Herrick. *Am. Geol.*, 18, 135–140. — The author finds that the "tripoli" of Socorro County, New Mexico is wholly inorganic in origin, consisting chiefly of minute scales of amorphous silica glass, due to the mechanical trituration and chemical alteration of an acid volcanic scoria occurring in the immediate vicinity. This view is sustained by microscopic observations, and a series of analyses by S. J. Gormley, of the New Mexican School of Mines.

On Pearceite, a Sulpharsenite of Silver. By S. L. Penfield. *Proc. Col. Sci. Soc., April* 6, 1896. — The author raises the arsenical variety of polybasite, Ag_9SbS_6, to the rank of a distinct species under the name pearceite, with the analogous formula Ag_9AsS_6. No new analyses are given, but those previously published by the author and others are quoted.

Clays of the Indianola Brick, Tile, and Pottery Works. By L. A. Youtz. *Proc. Iowa Acad. Sci.*, 3, 40–44. — The author gives several original analyses, quotes others for comparison, and discusses the suitability of the clays for various uses.

On Some of the Advances in Mineralogical Chemistry. By B. J. Harrington. *Proc. and Trans. Roy. Soc., Can.*, 1 (2), 3–17. — The importance of having pure materials for analysis is first noted, and the modern methods of accomplishing this by the use of the microscope, electro-magnets, liquids (solutions and fusions) of high density, and differential solvents are

briefly described. Among the analytic details to which the author gives attention are the distinction of ferrous and ferric iron in silicates, the estimation of water, the importance of making allowance for the iron pyrites in estimating the alkalies of rocks by Lawrence Smith's method, and the examination of minerals for elements which in many cases have escaped detection, the recent discovery of helium and argon in the mineral clèveite accentuating the importance of this work. The chemical constitution and molecular weights of mineral species next claim attention, and graphic formulæ of the several silicic acids and some of their salts are proposed. The synthesis of minerals is also briefly discussed.

Technical Chemistry.

F. H. Thorp, Reviewer.

On the Development of Smokeless Powder. By Charles E. Munroe. *J. Am. Chem. Soc.*, **18**, 819–839. — After an interesting review of gunpowder-making and testing, the author briefly describes the methods of preparing the more important smokeless powders, including an account of his own experiments leading to the discovery of indurite, the naval smokeless powder. — Pulped military gun cotton was dried and extracted with hot methyl alcohol. After drying, the insoluble, highly nitrated cellulose was mixed with nitrobenzene and incorporated with it on a grinding machine, so as to form a rubber-like mass, which was then granulated. It was then boiled with water, by which the nitrobenzene was removed, and the grains of nitrated cellulose became ivory-like in hardness and density. This process yielded a slow burning powder, containing no nitroglycerine, nor any oxidizing nor restraining admixtures, and giving very satisfactory results in the proving tests. — The requirements for a military powder and the methods for proving are given, together with tables showing the composition of various smokeless powders, and the results of tests of indurite at the Naval Ordnance Proving Ground.

Manufacture of Portland Cement in Belgium. By George W. Roosevelt. *U. S. Consular Rep.*, **52**, 184–191. — This is a *résumé* of the usual tests applied to cement. Several analyses and reports of tests made in American laboratories are included.

Process for Making Leather. By Samuel P. Sadtler. *Leather Manufacturer*, **6**, 102 (*Abstract of U. S. Pat. No.* 556,325). — Hides, after being prepared as usual for tanning, are impregnated with a chromate and an acid, and then submitted to the action of a dilute solution of hydrogen peroxide, or any peroxide, by which the chromic acid is reduced to chromic oxide, while oxygen gas escapes.

Process for Tanning Leather. By Sager Chadwick. *Leather Manufacturer*, **6**, 102 (*Abstract of U. S. Pat. No.* 561,044). — Skins which have been prepared in the usual way for tanning are immersed in a dilute chromic acid solution, and, when saturated, are transferred into a 10 per cent. solution of sulphate of iron in water. To either or both of these solutions acetic acid is added in the proportion of one part of acid to sixteen parts of the solution. Chromates or bichromates of soda, potash, or ammonia, may be substituted for chromic acid, and other iron salts may be used instead of the sulphate.

The Tannin Value of Some North American Trees. By H. TRIMBLE. *Garden and Forest*, 9, 162. — This article gives analyses of a number of American conifers, showing the percentage of tannin, moisture, and ash, which they contain.

On a New Process for the Manufacture of White Lead. By WILLIAM TATHAM. *J. Franklin Inst.*, 142, 309, 314. — The author gives a brief review of the well-known methods of preparing white lead, dwelling particularly on the disadvantages of each. He considers Bradley's patented process to be the most successful of the precipitation methods. In this a basic lead acetate solution, containing 11 per cent. of basic salt, is treated with carbonic acid at a temperature of 120° F., while flowing in thin layers over a series of shelves. But the essential point is that the process must be stopped when one half of the basic lead salt has been converted to white lead. The product contains from 30 to 37 per cent. of hydrated lead oxide, and is amorphous. The author proposes to stir finely powdered litharge into a solution of normal lead acetate until "the mixture crystallizes." By exposing the crystals to carbonic acid gas a basic carbonate is formed, while neutral lead acetate remains in solution. A solution containing 14 per cent. of normal acetate is treated with fourteen pounds of litharge to each cubic foot of the solution. Coarsely powdered litharge is used at first, but the final additions are made with litharge that has been passed through bolting cloth of 200 meshes to the square inch. The process is carried out in a steam-jacketed copper vessel provided with a stirring apparatus. After five or ten minutes the mass becomes curdy, and then a stream of carbonic acid gas is passed into the vessel. The crystals melt and are in part converted into white lead, which is separated from the lead acetate solution by the use of a filter press. Analyses of the various kinds of white lead are given, showing that this product approaches most nearly to the formula $2PbCO_3.Pb(OH)_2$.

The Electrolysis of Chlorides. By E. ANDREOLI. *Eng. Min. J*, 61, 568, 592. — The first of these papers is a review of the development and progress of the electrolytic production of chlorine and caustic soda. The second contains a discussion of the Castner-Kellner process, and comments on the Hargreaves-Bird process (see *J. Soc. Chem. Ind.*, 14, 1011.) In the author's opinion, the latter process has a promising future, though the former also appears to be a commercial success, and is much better than the Richardson-Holland method. Some doubt is implied concerning the economy of Le Sueur's process as compared with the Castner or Hargreaves method. According to Hargreaves, in the paper referred to, it is far more profitable for the manufacturer to make sodium carbonate than caustic soda.

A Contribution to the History of the Electrolysis of Alkaline Chlorides. By GEORGE LUNGE. *Eng. Min. J.*, 62, 224. — This is chiefly a criticism of certain statements in the article by Andreoli (see the previous abstract), in which it is represented that England and America have supplied all the practical inventions and real progress in the development of the electrolysis of chlorides. The author shows that electrolytic manufacture of chlorates was well established at Villers-sur-Hermes, in France, in 1889, Gall and Montlaur's process being used. Further, that a similar factory was opened in 1891, in Vallorbes, in Switzerland, and that the process is to be used in Savoy. He also shows that the production of alkali and chlorine by elec-

trolysis was established on an experimental scale in Germany as long ago as 1885, and commercial production began at the Griesheim works in 1890, the plant being enlarged in 1892. Since these dates other plants have been established in Germany. — On the other hand, no chlorates have been made in England on a large scale, the first plants for its production other than experimental having just been erected.

New Staffordshire Pottery Kilns. By WENDELL C. WARNER. *U. S. Consular Rep.*, 52, 80–85. — This is a short description of a new style of pottery kiln. Two diagrams are given.

Manufacture of Pulque in Mexico. By THOMAS T. CRITTENDEN. *U. S. Consular Rep.*, 51, 396–404. — This is an interesting account of the preparation of this drink, so largely consumed by the native Mexicans. Statistics of the industry and a translation of an analysis in the *Mexicana Pharmacopœia* are included.

Manufacture and Uses of Carbonic Acid in Germany. By FRANK H. MASON. *U. S. Consular Rep.*, 51, 756–762. — This is an extended review of this industry in Germany. The three chief uses for carbonic acid are for aërating effervescent beverages, for making carbonates and other chemical products, and in refrigerating machines. The greatest advance has been made in this industry within the last ten years, and it has now reached very large proportions. — When produced artificially the gas contains some impurities which render it unsuitable for aërating beverages, and for this purpose a natural gas is obtained by boring wells in the Rhine district; also, the gas escaping from many mineral springs is collected. Descriptions in detail of several wells and springs are given, showing this industry to be well established. There appears to be no direct connection between the gas and the strata where it is found, the gas probably being formed far below the earth's surface. The gas as collected is compressed to the liquid state and shipped in steel cylinders. The price is about five cents per pound in open market. The business is in the hands of a syndicate, which has about 45,000 flasks in constant use for transporting the liquid acid. — Carbonic acid, made by treating magnesite with sulphuric acid, is used extensively, and, as it is free from air, it is preferred for some purposes. When great purity is not essential, gas made in limekilns, or by passing steam over hot limestone, is used. Some gas is made by decomposing, with mineral acids, carbonates which are free from sulphur and bitumen.

Chrome Tannage Patents. By CHARLES S. FRIEDMANN. *Leather Manufacturer*, 6, 36. — This is a discussion of the Norris patents, Nos. 498,067, 498,214, 518,467, in view of the recent court decisions sustaining the Schultz patents. The author contends that sulphur is the *important element* in all the reducing agents mentioned in both patents. The Schultz patent names sulphites and sulphurous acid as the reducing materials, but the Norris patents specify sulphides and hydrogen sulphide, the same mineral acids being used in both cases. Since, by proper treatment, the sulphides can be converted to sulphites, and thus made to yield sulphurous acid when treated with mineral acids, the author claims that the Schultz patents must include all sulphur compounds, and hence the Norris patent is an infringement. The

author's assertion that sulphur is essential in the reducing substance for the preparation of leather is apparently contradicted by Sadtler's patent on the use of hydrogen peroxide (see abstract above) for this purpose. The reviewer would also question the formula, Na_2S, assigned to the bisulphite of soda.

Liming and Bating. By W. M. Norris. *Leather Manufacturer*, 6, 147. — This is the continuation of an article in the same journal (6, 132). After considering the properties of lime and the methods of slaking it, the author gives some figures relating to its solubility, and concludes from them that "excess of lime, if well slaked, would be more wasteful than injurious." — Red arsenic (As_2S_2) is always used with the lime for unhairing goat skins. The calcium sulphydrate formed is probably the active agent. A description of the method of preparing "limes" is given, together with certain theories concerning the process by which the sulphydrate and hydroxide of calcium in solution are "taken up by the skins." — Doubtless the expressions "$Ca(OH_2)$," "arsenic of lime," and "very limited insolubility of lime" are chargeable to the "intelligent compositor," whose handiwork in the production of chemical absurdities may frequently be observed in the pages of the above journal.

Note on the Presence of Oil in Boiler Scale. By Charles A. Doremus. *J. Am. Chem. Soc.*, 18, 741. — The author found a large proportion of matter soluble in ether, in the "cores" from cakes of artificial ice, made from condensed steam. The substance was fine, flocculent, and of a red color, and, when dried, was pulverulent and did not appear oily. The water from which the ice was made did not show visible oiliness when put into the freezing cans; but, on freezing, the iron and zinc hydrates, derived from the galvanized iron boxes in which the freezing was done, collected the oil and carried it to the "core." A specimen of scale from a Hudson River steamboat yielded considerable oil when extracted with ether. In the case of a boiler in Chicago, a fine clay in the river water together with incrusting matter caused the oil from the condensed water to form into balls. In a scale consisting of calcium carbonate, with sulphate and some clay, oil was present as a part of the "organic matter." In a similar scale from Lake Michigan water, sufficient oil was found to yield a considerable gas flame when the scale was heated in a test-tube. The author cites Lewes as authority for the statement that marine boilers have yielded scales containing from 20 to 50 per cent. of oil. He thinks it important to examine the nature of "organic matter" in boiler scales, the statement "loss or ignition" being too indefinite.

G. W. Rolfe, Reviewer.

Organic Solids not Sugars in Cane Juice. I. Nitrogenous Substances. By W. Maxwell. *La. Sta., Bull.* 38, 1371–1386. — An investigation of the nitrogen compounds of diffusion juice to ascertain why clarification is not as complete as in mill juice. The author shows that the diffusion juice contains less albuminoid nitrogen, the albuminoids presumably having been precipitated in the cane chips by the hot diffusion liquor. It is pointed out that the coagulating of these albuminoids is the chief factor in forming the necessary "blanket" in the clarification. The diffusion method, moreover, extracts more incoagulable nitrogenous matter which is not removed by clarification.

Organic Solids not Sugars in Cane Juice. II. Non-Nitrogenous Substances. By W. MAXWELL. *La. Sta., Bull.* 38, 1386–1395. — The author finds the so-called gums of sugar juice to be a mixture of vegetable mucilages and gums. They break up, by action of acids, to glucoses and cellulose. The small amount of true gums are pentosans, or they break up into pentoses. The author gives results of experiments on these gums with mercuric nitrate the electric current, and the action of freezing.

Dextran, One of the Gums of Our Sugarhouse. By G. C. TAYLOR. *La. Sta., Bull.* 38, 1334–1340. — The author has found that sugar solutions are rapidly converted into dextran by the action of a bacterium. He shows that the organisms are present, in large quantity, in massecuites and sugars. He estimates that 10 to 40 per cent. of the wagon-sugars of the State are destroyed by this growth.

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NOTE. — This index refers to only so much of the Review as was published in Vol. IX of the TECHNOLOGY QUARTERLY, and should be bound with that volume.

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